CONTROL SYSTEM DESIGNS FOR POTENTIAL RFID APPLICATIONS

by

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ABSTRACT

CONTROL SYSTEM DESIGNS FOR POTENTIAL RFID APPLICATIONS

RFID technology encloses diverse application areas that vary from industry to industry. Every year many new, previously potential use of RFID technology turns out to be an efficient application to the community and industry. In this study, current applications of the technology are investigated. Additionally control system designs proposed for two potential uses of RFID technology: (a) RFID Based Payment Control System for Stores, (b) RFID Based Employee Control System for Multi-Plant/Multi-Location Companies. It is seen that, functionality of the proposed systems is pretty encouraging for real life applications.

ÖZET

POTANSİYEL RFID UYGULAMALARI İÇİN KONTROL SİSTEMİ TASARIMLARI

RFID teknolojisi sanayiden sanayiye değişen farklı uygulamaları kapsamaktadır. Her yıl, daha önceden sadece potansiyel olarak görülen pekçok yeni kullanımı halkın ve sanayinin önüne verimli bir uygulama olarak çıkmaktadır. Bu çalışmada RFID teknolojisinin bugünkü kullanımları araştırılmış, ek olarak, gelecekte uygulama şansı bulabilecek iki uygulama için sistem tasarımı önerilmistir: (a) Süpermarketler için RFID tabanlı Ödeme Kontrol Sistemi, (b) Çoklu lokasyonlu şirketler için RFID tabanlı Çalışan Kontrol/Takip Sistemi. Çalışma sonucunda, sonuçların, fonksiyonel anlamda oldukça umut verici olduğu görülmüştür.

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LIST OF SYMBOLS/ABBREVIATIONS

RFID	Radio-frequency Identification
ISO	International Organization for Standardization
IFF	Identification of Friend or Foe
EAS	Electronic Article Surveillance
UHF	Ultra High Frequency
EPC	Electronic Product Code
EAN	European Article Numbering
UCC	Uniform Code Council
AIAG	Automotive Industry Action Group
HAG	Hardware Action Group
ANSI	American National Standards Institute
JAN	Japanese Article Number
MHz	Megahertz
GHz	Gigahertz
DC	Distribution Center
ROI	Return On Investment
NPV	Net Present Value
IRR	Internal Rate of Return
ED	Enterprise Dynamics
ISBN	International Standard Bibliographic Number
HR	Human Resources

1. INTRODUCTION

Over the past three decades, Radio-frequency identification (RFID) systems have evolved to become cornerstones of many different complex control applications. From first beginnings, RFID has been promoted as an innovation in convenience and monitoring efficiencies [1].

RFID is now rapidly becoming prominent in the contemporary business world. It has attracted extensive attention both from the business and the academic community and scattered into many broad and diverse control applications such as Smart Asset Tracking, Access Control, Supply Chain Management, Distribution Logistics, Product Identification, Ticketing, Smart Payment Systems, Vehicle Identification, Textile Identification, Smart Card Replacement, Gas Cylinder Tracking and Management, Product Management, Hospital Patient Identification and many more [2].

The applications for RFID Technology are seen limitless in terms of diversity and vary from industry to industry. Having a growing potential, every year a new, innovative use of RFID is launched. Limits for the use of RFID can be stated to be limited with the imagination of mankind.

The aim of this study is to design efficient and up-to-date RFID based control systems which will be new to the business application areas. For this study, RFID technology is examined, as well as its current applications and potential uses. Finally, two practical and potential control system designs, based on RFID, are brought up:

1. RFID Based Payment Control System for Stores (Electronic Self Check-Out Cashier)
2. RFID Based Employee Control System for Multi-Plant/Multi-Location Companies

The first control system design is focused on automatized payment, in which multiple tags are read concurrently and the total cost of transaction is credited from the customer's bank account. A human cashier is not needed, additionally; the calculation and waiting times in queues are almost eliminated.

The consumer shopping experience is expected to improve notably as a result of RFID-tagged merchandise. Checkouts can be nearly instantaneous because RFID readers can scan all tagged items in a shopping basket or cart in seconds without any items need to be physically removed and handled, resulting in increased efficiency, both for the company and the customer sides.

The second system design is focused on real-time employee tracking for Multi-Plant/Multi-Location Companies. A specific employee can be traced thorough the different locations of the company both for accessibility and security concerns, for the companies relying on alternative officing, in which the office locations are "unassigned" to any specific employee. Tracking reports are formed to identify current location of a specific employee, and attendance reports can be taken to be used as an analysis tool for the company.

In Chapter 2, related technologies and required background of this thesis will be presented. In Chapter 3, core parts of two control system designs involving RFID technology will be examined. The last chapter will summarize the work and discuss the future work which will improve and add value to the system.

2. BACKGROUND

2.1. RFID Fundamentals

Radio-Frequency Identification (RFID) refers to technologies and systems that use radio waves (wireless) to transmit information and uniquely identify and objects [3].

RFID uses wireless technology to convey data between microchip-embedded transponders and readers. The transponders or tags, consisting of a microchip and an antenna, are attached to objects that need identifying. The reader, using one or more antennae, reads the data held on the microchip. By emitting radio waves to the tag and receiving signals back, the reader is able to communicate with the transponder [3].

2.2. History of RFID

RFID systems have been around for decades and have been used in many different applications. But it was not until recently that RFID has started to receive enormous amount of attention from business corporations and commercial retailers [4].

One of the earliest uses of RFID was during WWII, when the long-ranged transponder system was explored. Identification of Friend or Foe (IFF) was one of the first practical uses of RFID, where military forces attempted to identify whether aircrafts were friendly or hostile [3].

The earliest commercial impact RFID had was during the late 1960s, when the electronic article surveillance (EAS) equipment was designed to counter theft and shoplifting. Although the EAS equipment consisted of only one-bit tags, it was an effective method to counter theft. Because only one-bit tags were used, the system could only detect whether an item was present, or absent. However, the system proved cost efficient, as the tags were relatively cheap and provided an effective way to prevent theft [3].

One of the first passive, read–write RFID tags was invented in the early 1970s. The transponder now included a way to store data, using a memory chip. It also responded to signals transmitted to write data into the memory, as well as data read from the memory. Furthermore, it transmitted a return signal out of the memory to the reader. The transponder also had a way to internally generate power to operate. This new invention was groundbreaking, as it opened the door for many new possibilities. With the ability to alter data in the tag, RFID tags became much more useful [3].

Following this invention in the 1970s, many tracking applications began to appear. RFID played a significant role in animal tracking, which is still used. Special tags are applied beneath the skin of animals, be it domestic, stock, or wild. The earliest form of animal tracking was used to analyze the migration route of different species of birds. The tag is usually in the form of a little glass pill, where information about the animal pertaining to its age, physical attributes, and health conditions can be stored and updated. The pill is placed under the skin of the animal and can in no way harm the carrier [4].

With the increasing uses of RFID in the 1980s, RFID systems began to break out in a significant way and have been emerging along 1990s and the twenty-first century, where commercialism plays such an influential role [2, 4].

2.3. Basic Components of an RFID System

RFID systems consist of two basic components: the reader (or scanner) and the tag (or transponder). The reader can contain one or more antennae to communicate with the tag. The tag, placed on the object to be identified, usually includes a microchip and an antenna [3, 5].

The communication between the reader and the tag uses a defined radio frequency and protocol. The reader transfers data to the tag, along with a clock signal from the reader to the tag to effectively label when the product was last checked. Some readers also provide energy to the transponder to activate and initiate the data transfer.

The tag itself carries the data used for object identification. Once the reader activates the tag, it can begin to read or write data onto the tag. A tag can be activated differently depending on the type of transponder used [5].

Briefly, Basic Operations of an active RFID is shown in Figure 2.1, below.

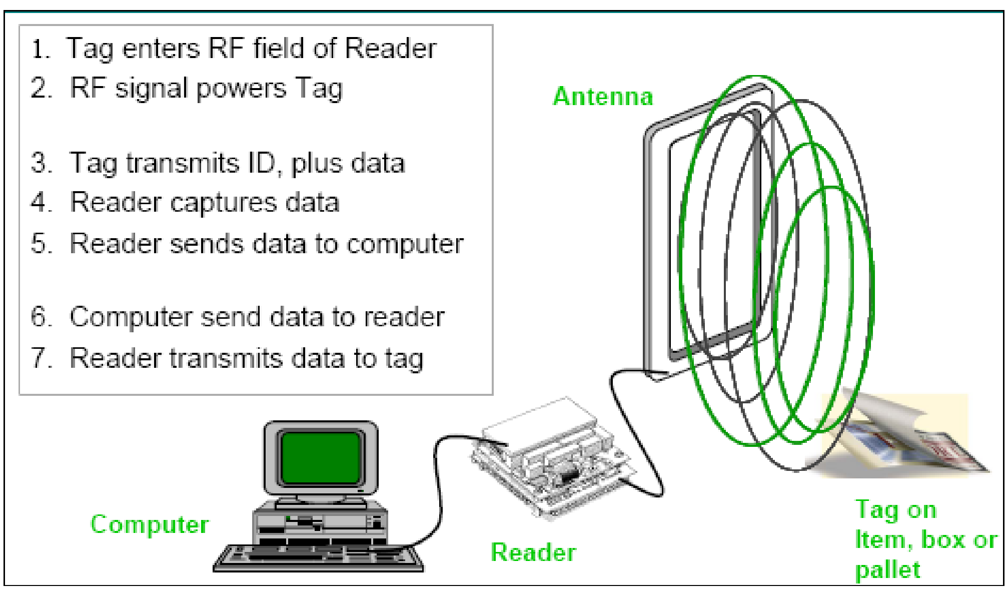

Figure 2.1. Basic Operations of RFID

2.3.1. RFID Tag (Transponder)

There are three main types of RFID tags: active, passive, and semi passive. Each type of tag is used for different application purposes, as their range and frequency limit them to certain viable functions [3, 5].

Active RFID tags have a power source such as a battery attached to the tag, in addition to larger memory and longer ranges than passive or semi passive tags. Active tags are able to broadcast data continuously on a set interval (from every few seconds to a few hours). Since active tags are used when identifying products that are deemed valuable and expensive, such as cars, the active tag must be able to communicate to the reader at long ranges and store much more information than passive tags. The typical read range of an active tag is usually somewhere between 20 and 100 m, and the batteries on the active tags last up to several years. The costs of active tags can range between $10 and $50 depending on memory size, the power of the battery, and the material used to design the tag.

Table 2.1. Comparison of RFID Tags by Power Source, Transmitter and Range

	passive	active	semipassive
power source	passive	battery	battery
transmitter	passive	active	passive
max. range (M)	10	100	100

Tags are usually passive unless activated by the reader. When the reader is near the tag, and the tag is in the "interrogation zone," the microchip on the tag is activated.

Simple tags are read only, where the reader can only access the data but cannot update or manipulate the data. Read–write tags are more expensive, but the reader can access the stored data within the tag as well as have the capability to change or update the data. Some more advanced tags include both a read-only chip and a read-write chip. The memory contained in the chip is programmed during production stages, and it would depend largely on the function of the tag and whether a large amount of memory is necessary for its designated task. The size of the tags would depend largely on which power supply, if any, was used, as well as the size of the antenna.

Although passive tags are the cheapest tags to produce at the moment, they are still not feasible in terms of production costs for many suppliers and retailers. The market expectation is to produce tags for less than $0.05 so as to enable widespread use of RFID. Economically, the supply and demand for RFID tags are too low for prices to drastically reduce anytime soon. Furthermore, many companies are not willing to invest enough money into RFID technology, because many of its applications are fairly new and are yet to be embraced by the general public [3].

While RFID technology is evidently increasing, companies are not willing to risk ordering large supplies of RFID tags at this level and cost. While the cost efficiency of using passive tags over active tags is undeniable, factors such as accuracy and reliability have made the use of active tags more common today. However, as research and development of passive tags begin to intensify, the commercial implications of passive RFID tags will undoubtedly drive costs down as there will be a high demand for them.

The following is a table of the most common RFID tags currently used [3]:

Table 2.2. Most Common RFID Tags Types

Tag Type	**Remarks**
Label	The tag is of a flat, thin, flexible form
Ticket	A flat, thin, flexible tag on paper
Card	A flat, thin tag embedded in tough plastic for long life
Glass bead	A small tag in a cylindrical glass bead, used for applications such as animal tagging
Integrated	The tag is integrated into the object it tags rather than applied as a separate label, such as molded into the object
Wristband	A tag inserted into a plastic wrist strap
Button	A small tag encapsulated in a rigid housing

A variety of RFID Tags can be seen on Figure 2.2., below

Figure 2.2. A variety of RFID Tags

2.3.2. RFID Reader

The RFID reader has three main functions: energizing, demodulating, and decoding. The reader, using a tuned antenna-capacitor circuit, emits a low-frequency radio wave field. This is used to power up the tag. The information sent by the tag must be demodulated (like an AM radio). The encoded information is decoded by the reader's on-board microcontroller.

Depending on the application and technology used, some interrogators not only read, but also remotely write to, the tags. Several types of reader exist. A number of companies manufacture them, and more are being developed for supply-chain RFID applications. Reader types include handheld, mobile mounted (forklift or cart), fixed read-only, and a combination of reader/encoder. In a typical distribution center, a set of readers would be configured to read any set of tags passing between them. Such a configuration is called a portal. Portals may be located in receiving dock doors, packaging lines, and shipping dock doors. Mobile mounted and handheld readers can be used to check tags that are not picked up through the portal, or to locate product in the DC or on trucks.

An RFID reader's structure is shown in Figure 2.3 [3], below

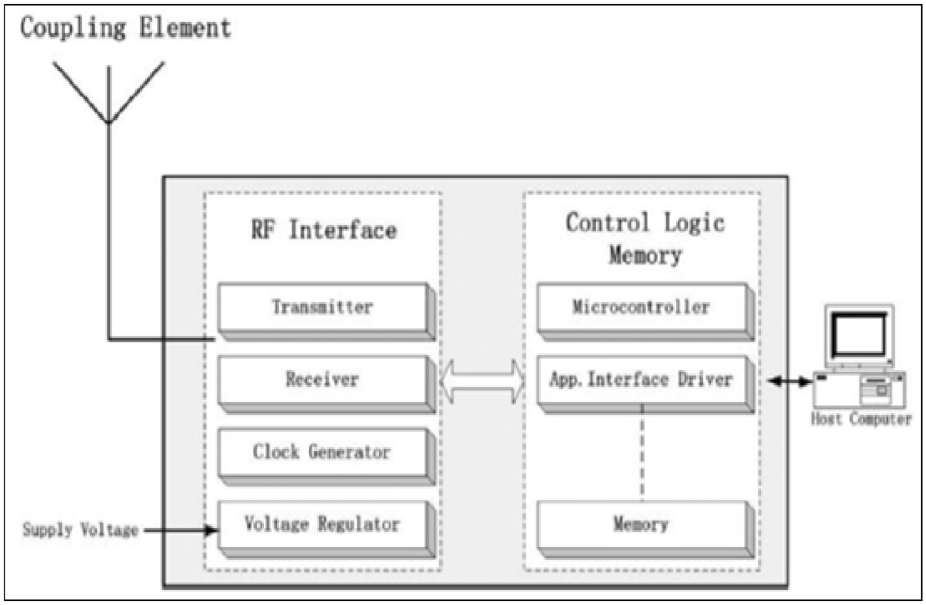

Figure 2.3. An RFID Reader's Structure

In both the reader and the tag, the antenna can be sized and shaped in different forms. Because of the small size of the tag, it can be formed to fit almost any situation. Since no contact is required, the RFID system allows great freedom of movement. Placement of the tag and reader is no longer critical.

Physical real-life examples of RFID readers in different sizes and shapes with associated electronics are shown in Figure 2.4.

Figure 2.4. Examples of Readers with Associated Electronics

2.3.3. Anti-collision

Because many tags may be available in the presence of a reader, the reader must be able to receive and manage many replies at once, potentially hundreds per second. Collision avoidance algorithms are used to allow tags to be sorted and individually selected. A reader can instruct some tags to wake up and others to go to sleep to suppress chatter. Once a tag is selected, the reader is able to perform a number of operations, such as reading the identification number and writing information to the tag in some cases. The reader then proceeds through the list to gather information from all the tags. This is like the relation between the teacher and students. When the teacher asks questions, if more than one student raises a hand, only one can be chosen by the teacher. Figure 2.5. shows the communication between a reader and three tags, and that the reader will communicate with only one tag at a time [3, 5].

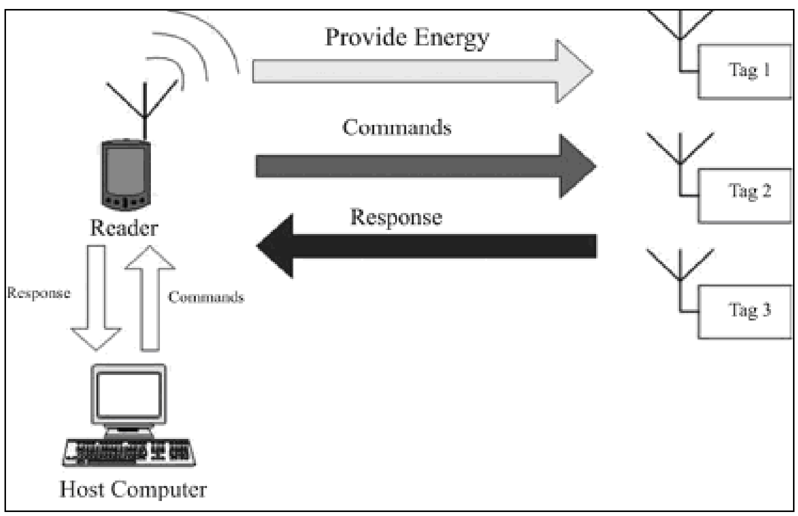

Figure 2.5. A reader communicating with three tags

2.3.4. Operating Frequency

There are several operating frequency bands that can be used for the RFID systems according to the radio licensing regulations [3]:

- Low frequency: between 125 and 134 kHz
- High frequency: 13.56 MHz
- UHF: 868 to 956 MHz
- Microwave: 2.45 GHz

UHF tags cannot be used globally as there are no global regulations for their usage. Factors that affect the choice of a suitable frequency for the applications include absorption in water, reflection on surfaces, energy demand, size of electronic parts, and speed of data transmission.

Below 135 kHz (LF):
• Short range –contact near to one meter
• Low data rates due to a lower bandwidth
• Penetrate nonmetallic materials (e.g., water)
• Do not penetrate/transmit around metals
• Used in access control, livestock, and wireless commerce

13.56 MHz (HF):
• ISM band
• Higher data rates and range
• Penetrate nonmetallic materials (e.g., water)
• Do not penetrate/transmit around metals
• Used in supply chain, wireless commerce, ticketing, and product authentication

860–930 MHz (UHF) :
• High data rate/long range
• Effective around metals
• Do not penetrate water
• Differences in frequency (Europe, USA, Japan)
• Used in supply chain, and toll tags

2.45 GHz (UHF):
• ISM band (same as Bluetooth, WLAN)
• High data rate, long range
• Effective around metals
• Do not penetrate water
• Used in logistics, and toll tags

2.3.5. Middleware Technology

RFID middleware technology handles RFID requirements by leveraging standard application development, data management, and process integration. RFID middleware includes basic features like reader integration and coordination, product ID data track-and-trace tools, and baseline filtering capabilities. The core capabilities are listed as follows [3]:

- Reader and device management
- Data management
- Application integration
- Partner integration
- Process management and application development
- Packaged RFID content
- Architecture scalability and administration

The capability of reader and device management allows users to configure, monitor, deploy, and issue commands directly to readers through a common interface, such as a command to turn off the reader. Like managing many other devices, a plug-and-play-like feature is desirable to dynamically sense the presence of the reader and link to it. In many applications such as those for container shipping business, in addition to RFID tags, there are other sensors such as temperature sensors. It is also important that RFID middleware have a capability of integration with other sensors, wireless and Internet technologies.

Data management is the ability of RFID middleware to be able to intelligently filter and route it to the appropriate destinations once product ID data are captured from readers. There are potentially hundreds of tags that may be present to a reader. The data management capability must allow the reader to filter out duplicate reads, and aggregate and manage product ID data in either a federated or central data source. It may also include more complex algorithms like content-based routing.

2.3.6. Standards

Standardization plays an essential role in terms of the mass adoption of technologies. RFID today is still in the stage of early adoption, while RFID standardization is still in development, especially in retail and supply chain. Currently, several organizations are active in the standardization of RFID technology. Leading institutions include the International Organization for Standardization (ISO), which is the worldwide union of national standardization institutions; EPCglobal, which is the joint venture of European Article Numbering and Uniform Code Council (EAN, UCC); and Ubiquitous ID Center, a Japanese industry RFID consortium. Some of the other institutions that work on RFID standards include the American National Standards Institute (ANSI) and the Automotive Industry Action Group (AIAG). The Chinese government has also declared developing its own standard for product information. Although there is a variety of RFID standard activities around the globe, RFID standards can be roughly classified into two groups, namely, application standards and technology standards. The standard structure is shown in Figure 2.6. In the following sections, three selected RFID standardization efforts, including ISO, EPCGlobal, and the Ubiquitous ID Center from Japan is presented [2, 3].

2.3.6.1. ISO: The International Organization for Standardization (ISO) is a union of national standard institutions from 145 countries working toward international standardization. The ISO has been active in the standardization of RFID internationally. ISO has had three committees that deal with RFID technology:

- TC104 (for freight containers)
- TC204 (for road informatics)
- TC122 (for packaging)

The ISO has proposed ISO 18000 for standardizing the air interface protocol, the specifications for allowing readers to communicate with tags. ISO 18000 does not specify criteria related to data content or the physical implementation of the tags and readers [3].

2.3.6.2. EPCglobal: EPCglobal is a Belgium-based non-profit joint venture between EAN and UCC. The mission of EPCglobal is to establish and maintain the Electronic Product Code (EPC) Network as the global standard to commercialize the use of RFID technology from the tags to data integration for immediate, automatic identification of any item in the supply chain in the world [6].

Within EPCglobal, the Hardware Action Group (HAG) develops specifications for key hardware components of the EPC Network, including tags and readers. The EPC system defines several classes of products [6]:

- Class 0: Read only passive tags, preprogrammed by the manufacturer
- Class 1: "Write-once read-many" passive tags that can be programmed by the manufacturer or by the user
- Class 2: Read/write passive tags, with memory or encryption functionality
- Class 3: Semi passive read/write tags, plus a battery-assisted power source to provide increased range and other functionalities on chip – memory, sensors, etc.
- Class 4: Active tags that can be reprogrammed many times, class 3 capabilities, plus active communication, and the ability to communicate with other active tags
- Class 5: Readers that can power class 1, 2, and 3 tags, as well as communication with class 4 and with each other

Like many other product codes used in commerce, EPC identifies the manufacturer and product type. However, EPC has an added set of digits for identifying each individual item. These digits collectively provide a unique identification for an item. An EPC number contains the following items and its structure is shown in Figure. 2.6 [5].

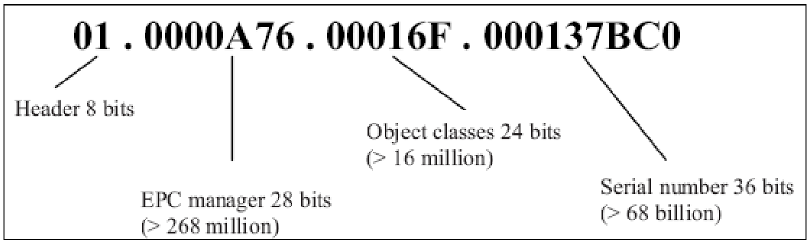

Figure 2.6. The structure of EPC (96 bits)

In this number format, "Header" is for identifying the length, type, structure, version, and generation of EPC, "Manager number" is for identifying the company and "Object class" is for identifying the class of objects to which an individual item belongs

Additional fields can be added to the e structure of EPC for encoding and decoding information from different product codes. In this case, EPC is just an information reference to the stored information about the individual item.

2.3.6.3. Ubiquitous ID Center: The Ubiquitous ID Center was formed to establish and popularize the core technology for automatically identifying physical objects and locations and to work toward the ultimate objective of realizing a ubiquitous computing environment [3].

In the ubiquitous ID architecture, real-world objects are embedded with ubiquitous ID tags (unique ubiquitous identification code or Ucode tags). These Ucode tags store ID codes (ubiquitous IDs) to distinguish their objects, along with some additional identifying information. The information that cannot be stored in Ucode tags is maintained in the database across the network.

The Ucode is the most fundamental element in the ubiquitous ID architecture that the Ubiquitous ID Center has developed. Currently, there are many different code systems applied to objects in the distribution sector and other fields. For example, JAN (Japanese Article Number) codes, EAN (European Article Number) codes, and UPC (Universal Product Code) codes are used in barcodes, while ISBN (International Standard Bibliographic Number) codes are used for books and other publications. These codes are assigned to the types of products, and they are not used to distinguish individual product item. In contrast, the Ucode is used to identify individual items. As a code, the Ucode is 128 bits long and can be extended as needed in 128-bit units to 256, 384, or 512 bits [5].

The greatest advantage of Ucode is that it can be used as a metacode system that can encompass various existing identification codes. With a length of 128 bits, it can accommodate many of these different numbers and identifications: from JAN, UPC, and EAN barcodes to ISBN publication IDs, and from IP addresses assigned by hosts for Internet connections to a telephone number. We use the JAN code as an example to explain how Ucode works. The standard JAN code is a 13-digit decimal. Expressing each digit of the decimal with 4 bits, we can express the entire JAN code with 52 bits [2]. The corresponding 128-bit Ucode is shown in Figure 2.7 [3].

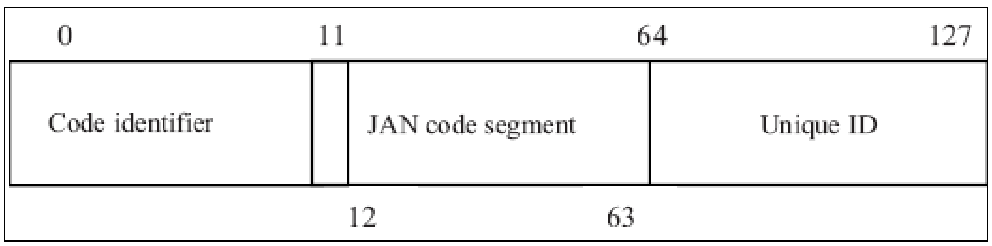

Figure 2.7. An Example of the Ucode Structure

2.3.6.4. Remarks on RFID Standards: Currently, there is no common RFID global standard [3]. As a result, many companies hesitate to adopt RFID because of potential compatibility issues. Some people worry that a universally accepted standard will never evolve. Let us take frequency as an example. It is clear that low frequency (9–135 KHz) and high-frequency (13.56 MHz) RFID tags can be used globally without a license. However, ultra high frequency (300–1200 MHz) cannot be used globally as there is no single global standard. In North America, UHF can be used unlicensed for 902–928 MHz, but this range of UHF is not accepted in France as it interferes with its military bandwidths.

In Europe UHF is under consideration for 862–870 MHz. For Australia and New Zealand, 915–927 MHz is the range of UHF for unlicensed use. For China, South Korea, and Japan, there is no regulation for the use of UHF yet. However, initial proposals have been made: for China, the proposed UHF is 915 MHz; for South Korea, the UHF range between 910 and 914 MHz is proposed; for Japan, the UHF range between 950 and 956 MHz is under consideration. The frequency 2.45 GHz is the frequency of microwave. The detailed allowable radiofrequency spectra around the world are shown in Figure 2.8 [3].

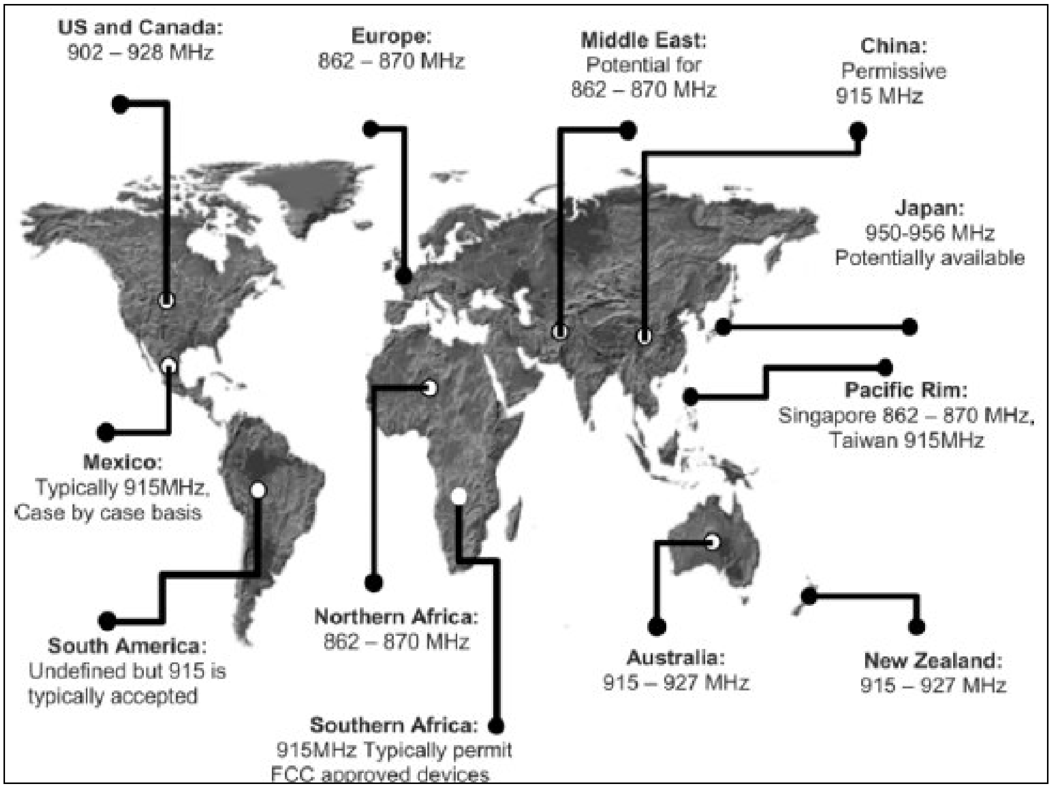

Figure 2.8. Allowable Radio Frequency Spectra Around the World [3]

2.4. Common Applications of RFID Systems

The concept of RFID is used as a method to identify friendly aircrafts during World War II. Recently, RFID receives great attentions. Operating frequencies, tags, and readers can be designed differently for different applications. In some applications, tags are read one-by-one as RFID tags pass a reader on a conveyor belt, while in other applications, multiple tags can be read at one time. RFID systems find various applications where automatic identifications of objects, people or locations are needed [1, 2, 3, 4, 5, 6, 7]. Some examples of applications are listed as follows:

- Access Control
- Animal identification and tracking
- Human identification
- Product identification and tracking
- Tools/Container/Mold identification and tracking
- Warehouse Automation / Supply Chain Management
- Inventory systems
- Electronic Toll Collection and Road Pricing
- Lap scoring in sports
- Library items management
- Passports and ID cards
- Laundry Identification
- Automated Guided Vehicles
- Human implants
- Identification of Patients and Hospital Staff
- Customer Loyalty Programs and Customer Relations Management
- ID Prescriptions in Automated Pharmaceutical Systems
- Mining Conveyor Belt Identification
- Automated Airline Baggage Systems
- Identify/Track Rental Items
- Replacing barcodes
- Investigation of Motor Vehicle Accidents

- Security and National Defense applications
- Building automation
- Intelligent tire
- Recycling of materials in vehicles
- Radiation detection
- Tsunami detection
- Golf course ground management
- Quality control
- Spare-part warehousing
- Serial number look-up
- Hazardous waste management
- Industrial robotics
- Gas pipeline monitoring
- Scrap handling
- Conveyor systems
- Display advertising
- Mobile phone interacting with payment systems
- Banknotes
- Passports
- Detection of counterfeit goods
- Disaster management
- Home automation

3. RFID BASED PAYMENT AND EMPLOYEE CONTROL MODELS

3.1. RFID Based Payment Control System for Stores

With the RFID technology, we can imagine shopping without money, sales clerks or even cash registers. All we have to do is walk in, find the items and walk out with the shopping cart. In the not-so-distant future, RFID technology within retail stores recognize the picked items and while the customer leave, the system will charge the total amount in the cart from customer's bank account automatically.

The University of Arkansas RFID Research Center is working with a major retail industry organization and a global supply chain association to explore the feasibility and value of using radio-frequency identification technology for item-level tagging of apparel and footwear. The project will generate greater inventory efficiency for retailers and product availability for consumers. Taken further, the research could lead to purchasing items without a cash register [34]. "It sounds utopian," said Bill Hardgrave, director of the university's RFID Research Center, "but it isn't that far-fetched when you consider the unique capability of RFID technology and implications of this research, if it is successful.

With modifications to current technology, shoppers shouldn't have to wait in line for a clerk to ring up their items. Although this system will have major advantages for retailers and suppliers, item-level tagging will lead to even greater advantages for consumers. Of course this kind of am RFID payment and sales control system must be sensitive to consider protecting a consumer's right to privacy [8]. Current, that is year 2008 status of the self check-out is given in section 3.1.7..

3.1.1. General Definitions

To be clearer, we should define the types of stores. According to the Progressive Grocer's 2005 Marketing Guidebook [9] stores are classified and defined as below:

3.1.1.1. By Type of Store: "Grocery Store" is any retail store selling a line of dry grocery, canned goods or nonfood items plus some perishable items. Type of store named, "Supermarket" is any full-line self-service grocery store generating a sales volume of $2 million or more annually. "Convenience Store" means any full-line, self-service grocery store offering limited line of high-convenience items. Open long hours and provides easy access. The majority sell gasoline with an annual sale of $2 million or more. “Chain” implies an operator of 11 or more retail stores.

3.1.1.2. By Store Format: “Conventional Supermarket” is the original supermarket format offering a full line of groceries, meat, and produce with at least $2 million in annual sales. These stores typically carry approximately 15,000 items; offer a service deli and frequently a service bakery. ”Superstore” is a larger version of the conventional supermarket with at least 40,000 square feet in total selling area and 25,000 items. Superstores offer an expanded selection of non-foods. Format of store named “Food/Drug Combo” is a combination of superstore and drug store under a single roof, with common checkouts. Non-food products represents at least one-third of the selling area and approximately 15% of store sales. These stores also have a pharmacy. Another format is “Warehouse Store”, is a low-margin grocery store offering reduced variety, lower service levels, minimal decor, and a streamlined merchandising presentation, along with aggressive pricing. Generally, warehouse stores don't offer specialty departments. The other types are “Super Warehouse”, “Limited-Assortment Store” and “Convenience Store (Traditional)”, “Convenience Store (Petroleum-Based)”.

3.1.2. Problem Definition

Human operated checkout and payment leads to inefficiency both on the customer and company sides.

While a customer spends time to pick the items from the shelves, he does the reverse to pay for the goods bought, which can be seen as a repetitive action. At a store, a customer typically spends anything from 10 to 20 minutes queuing to get to the check-out. This is, without adding any value, amount of time wasted by the customer [10].

Additionally, inefficiency of human operated payment calculation and payment is dramatic for the other customers waiting in line. The first customer’s check-out time is added to all the other customers’ waiting time in the queue.

Cost of hiring cashiers, decreased customer that can be served per day, decreased customer satisfaction and risk of human errors in payment processing are just a few inefficiency types for the company.

Briefly, the problem consists of a number of factors [22]:

- Number of items being purchased
- Efficiency of buyer to unload the basket/cart
- Efficiency of the cashier to scan the items : other than the, rather longer (compared to RFID) read time of barcode, torn or harmed barcodes decrease the scanning efficiency of barcode data
- Efficiency of cashier/customer to pack the items post-purchase
- Efficiency of payment processing

3.1.2.1. Number of Items: We can assume that the greater the number of items, the longer it will take to get through the checkout. This is true above a certain quantity of items. Below this critical mass, the weight of the other factors takes precedence, rendering buys of less than, say, 10 items not affected by the quantity of items. According to Food Marketing Institute (FMI), 45 items are carried in a supermarket shopping in 2006, on the average [10].

3.1.2.2. Cart Unload Time: Unloading the cart to make the bought goods scanned by the human cashier takes considerable time, especially on weekends when customers do their weekly gross shopping and in some hours of weekdays. Here, the greater the number of items, the longer it will take to unload the cart assumption applies.

3.1.2.3. Item scanning: In today's supermarkets barcodes are used to calculate the total shopping amount. Supermarkets began barcode scanning in 1974. The first item scanned in a commercial environment was a pack of Wrigley chewing gum in Marsh Supermarkets on June 26, 1974 [32]. Barcodes became the "revolutionary lifesavers" of the supermarkets when they first introduced but today barcodes are not enough to melt supermarket queues. Because barcodes have serious conceptual limitations to scan an item:

- Scanning with barcode requires human operation
- Barcodes are read-only

- Proximity to the barcode reader is required
- Visibility of barcode for the reader is required
- Only one barcode can be scanned at a time
- Barcodes are easy to be imitated
- Reading times can go up 4 seconds per item
- Reading success is dependent on the quality of print and the surface that is scanned
- Barcodes are quite vulnerable to physical damage
- Amount of data carried is limited

Even if it seems that the time to scan each item takes half second, in fact, for a weekend shopping it takes minutes for the whole cart. Depending on the number of items to scan, the scanning time increases in a proportional manner.

3.1.2.4. Post-purchase packing: After all the items are scanned, the customer must pack the goods just at the same place he paid. For the most of the time, before the current customer finishes to pack the goods, the scanning process of the next customer starts and usually bought or packed items of these two customers cannot be distinguished; ownership of items are confused. Additionally, next customer must wait the current one to pack, before he can pack his own items.

3.1.2.5. Payment processing: Conventional payment processing in today's stores involves too much human action, even if the credit cards are used instead of cash. Process requires the following steps: Taking the customer's credit card, putting it into reader, expecting final approval for the cashier machine, waiting for payment processing, waiting for the bill, giving bill and the credit card back to the customer. With cash payment, the situation is less standardized and open to many different inefficiencies caused by human error.

3.1.3. Solution Proposal

RFID based payment for the items in a shopping cart can improve the efficiency of human operated check-outs, both on the cashier and the customer sides.

By introducing RFID, it is possible to remove two of the above factors out of the equation. These are "Cart unloading" and "Item scanning". RFID does not require an individual to pass the product in front of a laser beam in order for it to register with the

POS system. Instead, low-powered radio frequencies are used to provide all the information a barcode scan and database lookup would provide.

By removing the scanning factor, together with the increased adoption of electronic payments, it eliminates the necessity for the cashier to be present at the checkout.

By adding a Credit card reader and RFID scanner before the exit door, a further two factors can be removed formed the equation (namely, “Payment processing” and “Number of items”). With the on-board card reader, preliminary payment processing can begin as soon as the card is inserted. As the shopper moves out of the store, the customer passes through the RFID scanner “tunnel”. As a result purchase bill’s total amount is deducted from the customer’s credit card.

Post purchase packing will be much efficient for the customers since they don’t have to wait previous customer and no jamming will occur since the customer can pack his items any place he wants.

Briefly, the whole supermarket experience can be improved by using RFID .

3.1.4. Proposed System Design

A preferred embodiment for self-checkout includes a housing having a tunnel or a corridor for receiving articles for self-checkout. The tunnel is placed within a deactivation zone. The RFID tags are read, and after verification of an authorized transaction, a deactivation antenna is energized to deactivate the RFID tags, and a stored inventory database is updated. Information about the transaction can also be displayed. A preferred embodiment for self-check-in includes an elongated housing into which articles are deposited for return. Once deposited, the articles pass through the housing and out the other end. As the articles are deposited, the RFID tags on the articles are read, the inventory database is updated, and an activation antenna is energized to form an activation zone through which the articles pass as they fall through the housing, thus activating the attached RFID tags.

3.1.4.1. Elements of the system: The proposed system consists of elements listed below. They are divided them into 4 logical groups. These groups and items included in them are listed below:

Customer

- Credit card: Keeps Credit card data and pin code
- Credit card reader: Reads Credit card data

Product

- Product tag: Keeps ID information of the product

Bank

- Bank server: The server keeps customer, credit card and account data. Relevant computations and transaction processing is made on this server. Data traffic is also directed on this server.

Store

- RFID Tag reader: Reads the Product ID data on the RFID tag
- Store server: The server keeps product and customer account data and makes relevant calculations and directs data flow between the components of the system. Main shopping transactions are run on this server. A database is kept on this server for products, transactions and peripheral device management.
- Invoice printer: Prints the invoice of customer transactions after the shopping transaction processing
- RF cashier screen: User interface for transaction information to the customer. Messages and/or warnings are shown, when relevant.
- Lock door: Keeps locked until the customer transaction is approved. When the transaction is successful it opens.
- Take back niche (optional): When the customer wants to leave some of the things bought because of the past sell-by dates, uses this physical niche. The cost of items left in this niche is paid back to the customer.
- Plastic bag dispenser: Involves in the system because of the need of customer to pack the items bought. This component does not have any electronic use in this

RFID system. This is a complementary element that will not play a role in the RFID system proposed, directly.

- Additionally, design can include No-Buy Tunnel for the customers who don't buy any item.

<u>3.1.4.2. Physical Structure of the Store and Process Flow Chart:</u> Physical Structure of the Store can be seen in Figure 3.1, below.

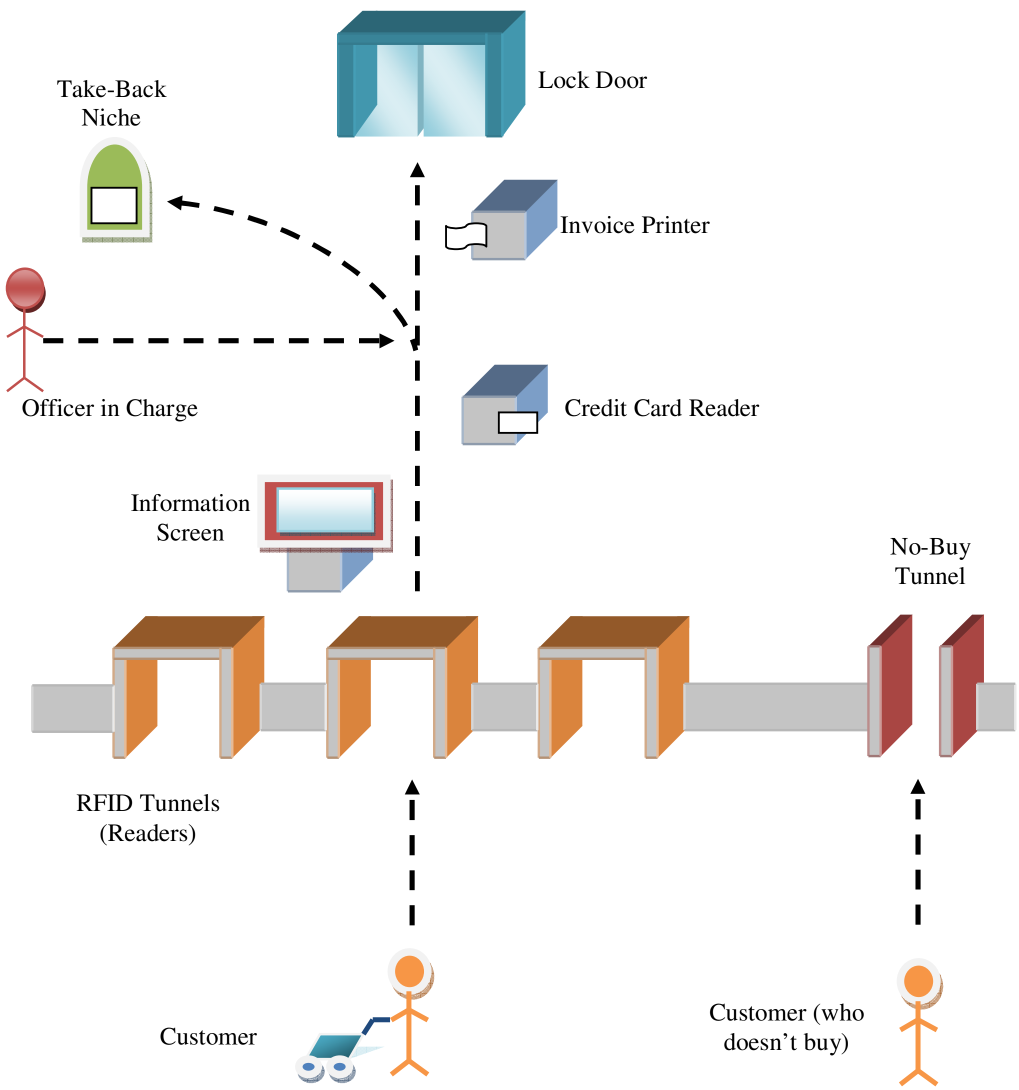

Figure 3.1. Physical Structure of the Store

The general process flow is demonstrated on Figure 3.2.

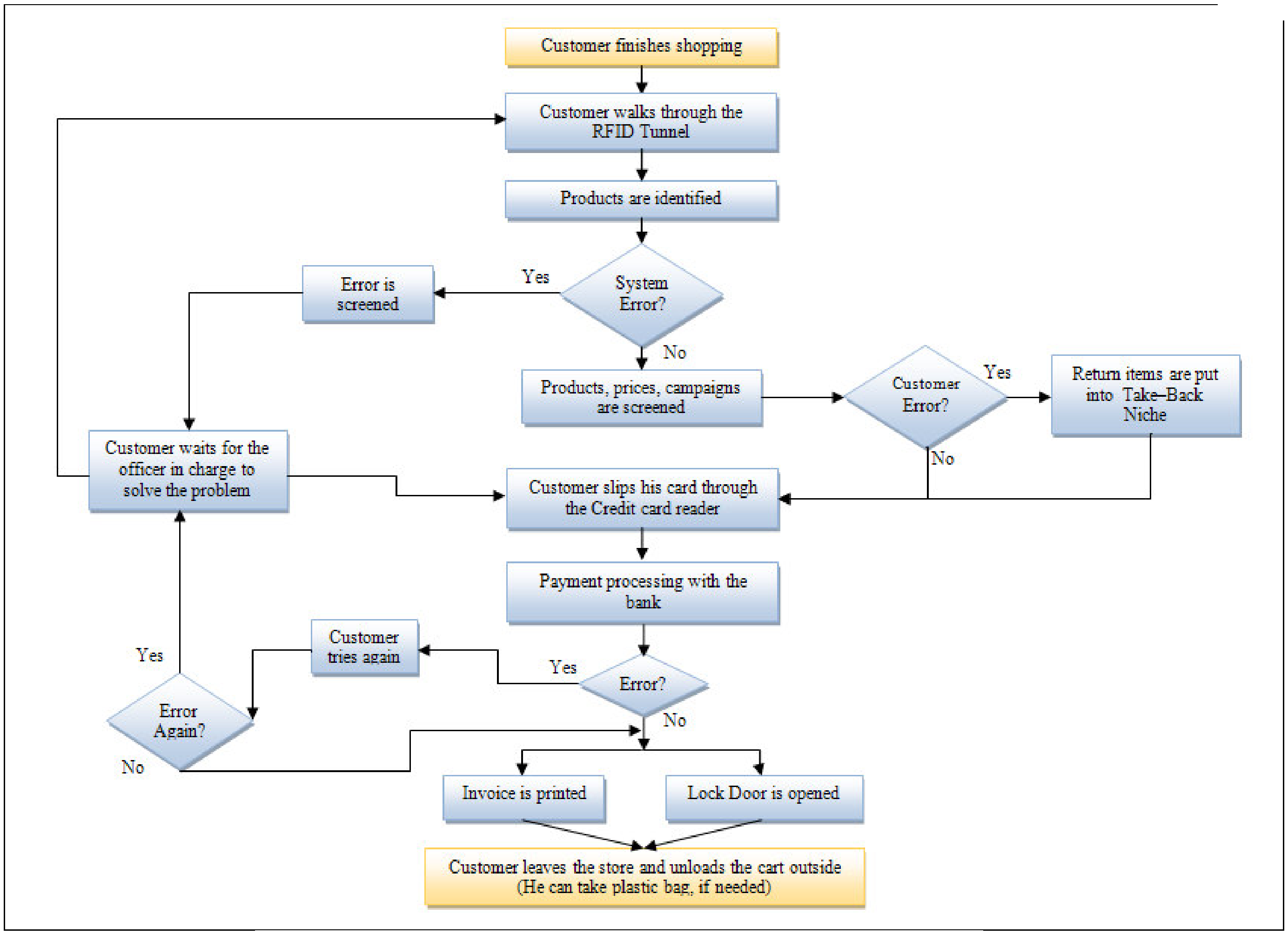

Figure 3.2. General Process Flow – Self Check-Out Model

3.1.4.3. Input for the system: Besides the elements of the system, database tables on the servers keep input data like product details and prices, readers, cashiers, campaigns for specific products, predefined messages and taxation rules.

3.1.4.4. Outputs of the system: With the relevant input and triggering actions of customer and the software running on the servers system creates transactions and invoices kept on database tables, payment processes and their outputs, warning messages, bank account updates, item amount updates for the warehouse.

An invoice delivered to the customer is a physical output of the system given (see Figure 3.3) and on the cashier screen, a few meters away from the check-out tunnel, relevant data is screened (see Figure 3.4).

3.1.4.5. Database Tables for the Proposed System: The data elements of the proposed self-check-out system are shown in the following database tables. The following database tables are stored and processed on Store server.

Table 3.1. RF_Cashiers Database Table

RF_Cashiers
RF Cashier ID

Table 3.2. Products Database Table

Products
Product ID
Product Definition (Name)
Unit Price
Incurred VAT
Amount in the warehouse

Table 3.3. Campaigns Database Table

Campaigns
Campaign ID
Campaign Name
Discount Rate
Discount Amount

Table 3.4. SM Messages Database Table

SM Messages
SM message ID
SM message Text

Table 3.5. Credit_Card_Readers Database Table

Credit_Card_Readers
CC Reader ID

Table 3.6. ProductsCampaigns Database Table

ProductsCampaigns
ProductCampaign ID
Product ID
Campaign ID

Table 3.7. TransactionsHeader Database Table

TransactionsHeader
Transaction Aggregate ID
Total Sum
RF Cashier ID
SM message ID
Invoice ID (Issued)
CC Reader ID
Credit Card ID
Credit Card Number
Credit Card Type
Customer Name

Table 3.8. Transactions Database Table

Transactions
Transaction ID
Transaction Aggregate ID
Line Number
Product ID
Item amount (No. Of Reads of same Product)
ProductCampaign ID
Discount Total
SubTotal
Incurred VAT
Incurred VAT Amount
Transaction Date
Transaction Time
Transaction Sent Date
Transaction Sent Time

Table 3.9. Invoices Database Table

Invoices
Invoice ID
Invoice Issue Date
Invoice Issue Time

The following database tables are stored and processed on Store server.

Table 3.10. Bank_Customer_Data Database Table

Bank_Customer_Data
Customer ID
Customer National ID Number
Customer Name
Customer Taxation Number
Customer Address
Customer City
Customer Country
Branch Bank ID
Branch Bank Name
Account Number
Credit Card ID
Credit Card Number
Credit Card Type
Credit Card Expiration Date
Credit Card Limit
Credit Card Limit Used
Credit Card Limit To be Used

Table 3.11. Bank_Messages Database Table

Bank_Messages
Bank message ID
Bank message Text

Table 3.12. Bank_Transactions Database Table

Bank_Transactions
Customer ID
Customer Identity Number
Customer Name
Customer Taxation Number
Credit Card ID
Credit Card Number
Credit Card Type
Account Number
Credit Card Limit Update (- or +)
Account Update (- or +)
Bank message ID
Bank message Text
Bank Transaction Date
Bank Transaction Time
Bank Transaction SentBack Date
Bank Transaction SentBack Time

<u>3.1.4.6. Physical Outputs:</u> Outputs of the system are “Invoice” and Data on “Cashier Screen”. The invoice below is printed by the Invoice printer after a successful payment processing. Printer is located a few meters away from the check-out tunnel.

Company Logo	*Company Name*		
Invoice no	*0000056*		
Date	*05.08.2007*	**at**	*15:24:55*
Cashier			
Detergent 3 kg			
x	*1*		
$	*12,25*		
Supermarket discount Festival - Special Price			
Discount	*1,20*		
SubTotal			
$	*11,05*		
VAT	*1,99*	*18%*	
Yoghurt 500 gr			
x	*2*		
$	*2,58*		
Brand Special Discount - Seasonal			
Discount	*0,15*		
SubTotal			
$	*4,86*		
VAT	*0,87*	*18%*	
20 pack chewing gum			
x	*4*		
$	*0,50*		
SubTotal			
$	*2,00*		
VAT	*0,36*	*18%*	
TOTAL	*17,91*		
THANK YOU!			

Figure 3.3. Invoice

Between the tunnel and the Invoice printer, an informative screen is located to make a customer aware about the success of the transaction, and to warn customer for unsuccessful processes. For a successful transaction, the content of the shopping is given in detail. A typical screenshot is given below:

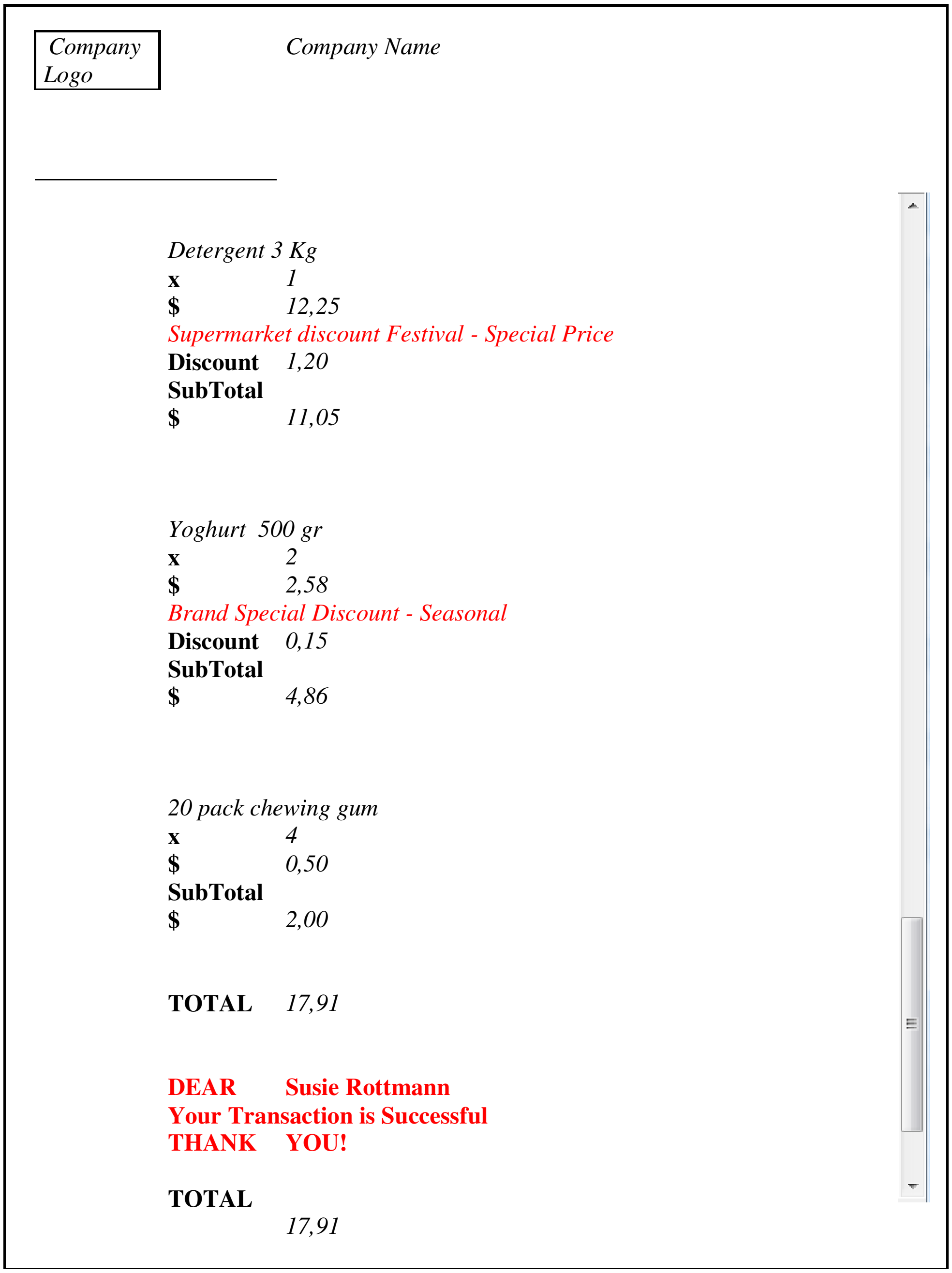

Figure 3.4. Cashier Screen

3.1.4.7. Data Flow between the components of the system: In this study, XML format is proposed to be used through the whole system, where possible. If not, other data structures for data exchange can be used. But at least, XML format is used to show data exchange between the components of the system. Today's popular data exchange structure has many advantages over the other formats.

3.1.4.8. Data Flow Diagram: On the diagram, data flow paths are shown with arrows including the direction of the flow and arrows are given numbers. In Appendix A.1., XML data is shown with those respective flow numbers.

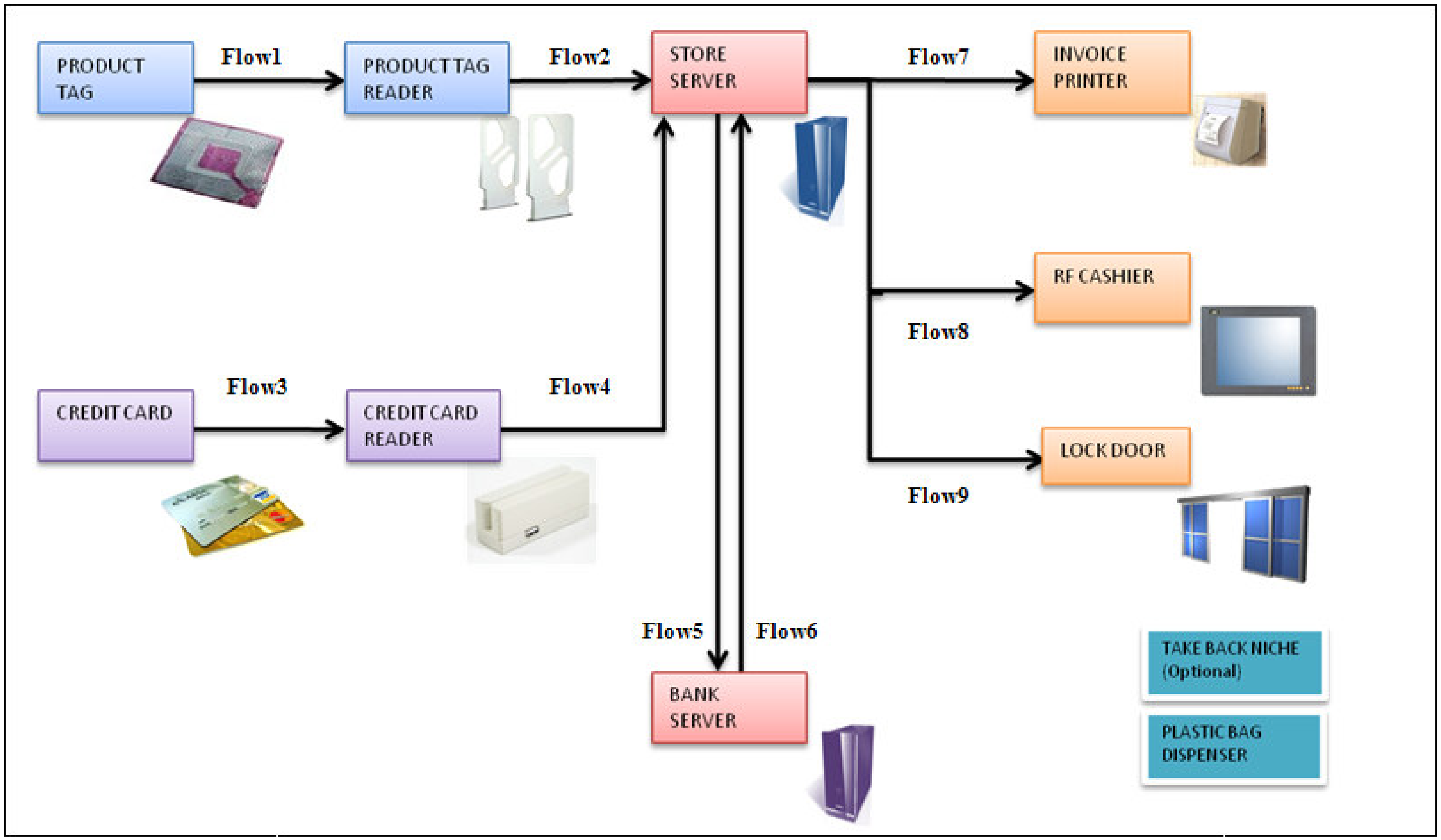

Figure 3.5. Data Flow Diagram – Self Check-Out Model

3.1.4.9. Internal Data Computation on the Server: Other than data flows between elements, the calculations are done on the servers and written on the related database fields.

3.1.5. Analysis and Comparison and of the Proposed System Simulation

In order to observe the proposed system outputs and discover the possible benefits of the system, a simulation model is constructed and the outputs are analyzed. In order to compare the proposed self check-out model with the classical check-out, another simulation model with the same parameter when possible is constructed as well. Outputs of the models are compared in the subsequent sections.

In this study, Student Version of "Enterprise Dynamics 7 Studio" software [35] is used for simulating the models. Enterprise Dynamics is an object-oriented software program for modeling, simulation, visualization, and control of dynamic processes. The users can pick up objects - called "atoms" - from standard libraries in order to build their own model. ED is based on this concept of atoms as modeling objects in each model.

3.1.5.1. Elements of Simulations

3.1.5.1.1. Classical Check-Out Model: For the classical check-out from the market with a human cashier model, the blocks, that is the elements of the simulation is listed below.

- AisleExit
- StoreExit
- Queue_Cust
- Unload
- Queue_Items
- Cashier (Scan and Pay)
- Queue_PackIt
- Pack

AisleExit and StoreExit "blocks" of the simulation denotes the source and the sink blocks, respectively. These provide customer inflow to the operator, the human cashier for barcode scanning and payment processing. The block named "Unload" denotes the unloading of the items to be scanned from the cart to the cashier deck. This is an operation block. Between the released customer from the source “AisleExit” and the operation block of “Unload”, a queue named “Queue_Cust” is placed. This is the queue of customers waiting to be served by the human cashier. The operator block “Cashier (Scan and Pay)” simulates the human cashier operation in item basis. Cashier spends some specified time per item to scan and get the payment. Between the “Unload” and “Cashier (Scan and Pay)” operations, another queue, “Queue_Items” stands, is denoting the unloaded items which are waiting to be scanned by the cashier. After scanning the items are taken to the rear side of the cashier, into the queue named “Queue_PackIt”, collecting the items to be packed by the customer. Packing operation is performed in the block named “Pack”. The structure of the simulation model is shown in Figure 3.6.

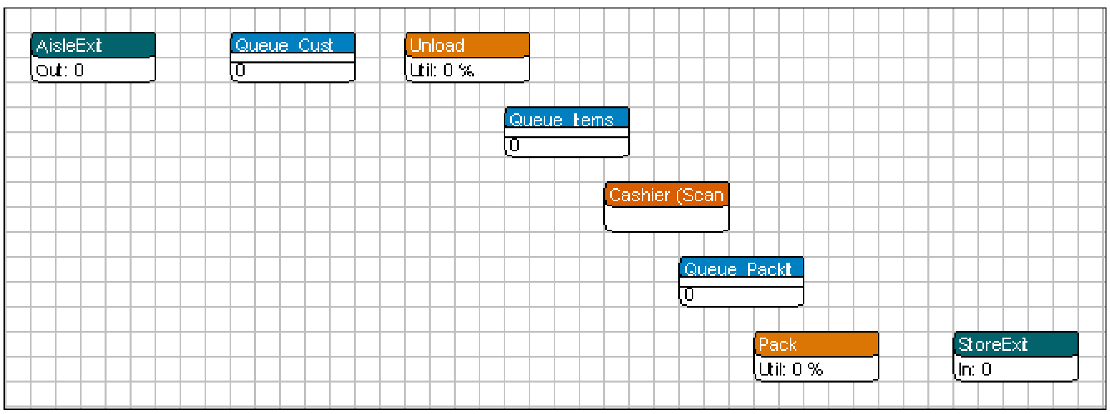

Figure 3.6. Block Structure of the Simulation for Classical Model

The figure below shows the item and customer flow for the blocks of simulation (See Figure 3.7):

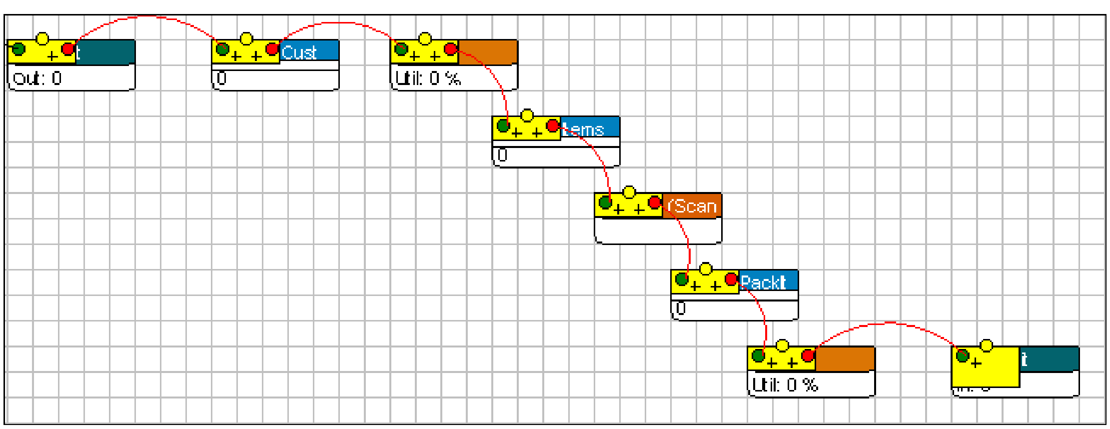

Figure 3.7. Flow Structure of the Simulation for Classical Model

3.1.5.1.2. Proposed RFID Check-Out Model: For the Proposed RFID check-out model, the blocks of the simulation are listed below. There are common blocks with the previous model, and the same parameters are used when it makes sense.

- AisleExit
- Queue_Cust
- RFIDCashier
- Queue_Payment
- CCPayment
- StoreExit

Again, AisleExit and StoreExit "blocks" of the simulation denotes the source and the sink blocks, respectively. The block named "RFIDCashier" denotes RFID tunnel under which the RFID readers receive product and price data of the items in the cart. In this model there is no unloading operation since the customer only walks out of the store with his cart The item scanning operation via RFID technology is performed in this block. Between the released customer from the source "AisleExit" and the operation block of "RFIDCashier", a queue named "Queue_Cust" is placed again. This is the queue of customers waiting to pass through the RFID reader tunnel. The operation block "CCPayment" simulates the customer's passing his credit card through the classical credit card reader. Customer spends some specified time to pay the total value of the shopping via credit card reader by himself. Between the "RFIDCashier" and "CCPayment" operations, another queue, "Queue_Payment" is put to denote the queue of the customer waiting to pay for the shopping with credit card. The structure of the simulation model is shown in Figure 3.8.

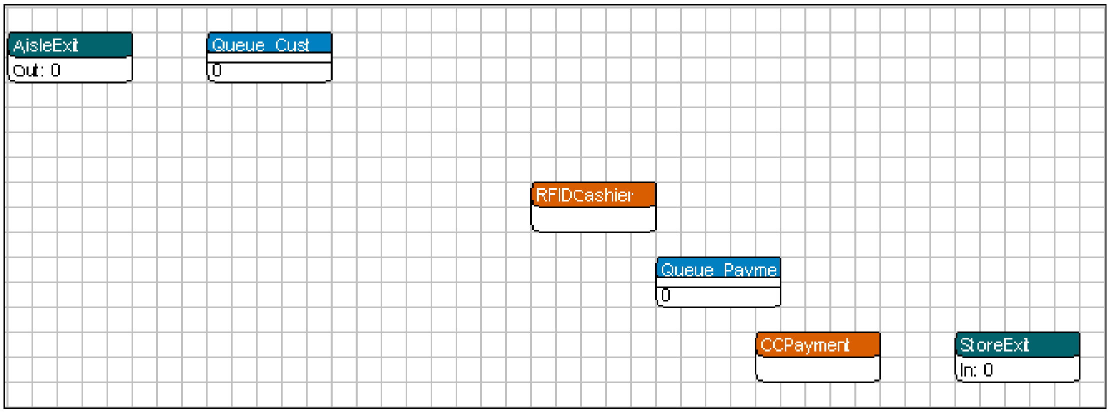

Figure 3.8. Block Structure of the Simulation for Proposed Model

The figure below shows the item and customer flow for the blocks of simulation (Figure 3.9):

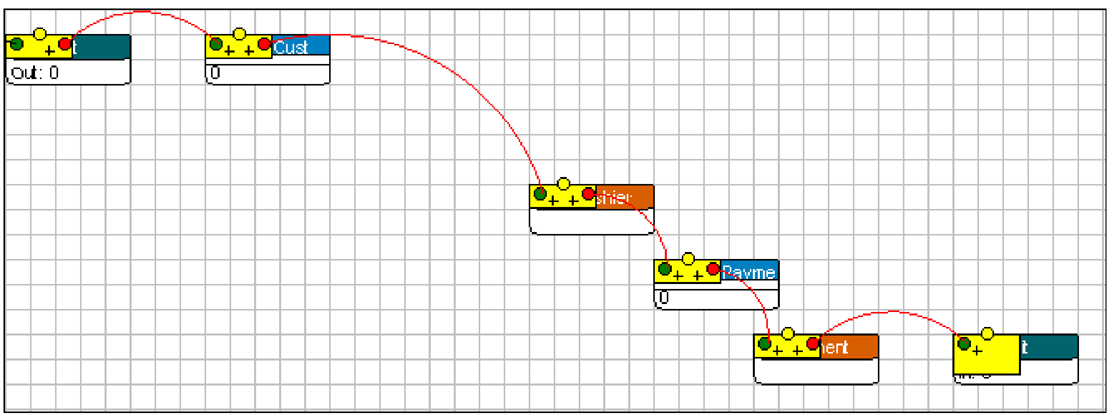

Figure 3.9. Flow Structure of the Simulation for Proposed Model

3.1.5.2. Parameters of Simulations: Parameters of the simulation models are given for each, below.

3.1.5.2.1. Classical Check-Out Model

Customer arrival (AisleExit):

- Customer arrives randomly with inter-arrival time of 30 seconds. For this block, the negative exponential distribution is used, which is a probability distribution often applied in unpredictable arrival or service processes.
- Time till first customer is 10 seconds after the simulation begins.

Queue before Human cashier (Queue_Cust):

- Queue capacity is 15 customers
- Queue discipline is First-in-First-out

Unloading the products (Unload)

- There is no set-up time for unloading.
- The unloading time is uniformly distributed. The unload time is uniformly distributed from 20 to 40 seconds for each customer. (Uniform(20,40))
- The Batch factor is taken as 20, that is, every customer brings 20 items, on the average. In the simulation when 1 customer unloads, in the rest of the simulation, 1 customer turns with 20 items for simulation. Since the model concerns customer queues and payment time mainly, this transformation is made when needed.

Pool (Queue) of Unloaded items (Queue_Items):

- Since there is another limit; the capacity of the deck on which the items waiting to be barcode scanned by the human operator, in the classical payment method. It is taken as a queue with a capacity of 200 items.
- Queue discipline is First-in-First-out

Human cashier Barcode Scanning each item and payment

- To make the model simpler, credit card payment is included with the scanning. Since the barcode scanning has always been much longer, the payment time can be included as an average factor effecting the average time of the process.
- There is no set-up time.
- Barcode scanning (included calculated average payment time for each item) per item is uniformly distributed; 0.5 to 1 seconds (Uniform(0.5,1))

Pool (Queue) for packing the items (Queue_PackIt)

- Since there is another limit; the capacity of the deck on the rear side of the human cashier. Here, the scanned items wait to be packed. It is taken as queue with a capacity of 75 items.
- Queue discipline is First-in-First-out

Item Packing (Pack)

Customer packs the items after scanning. Since each customer brings 20 items on the average, The Batch factor is taken as 20. In this block, the unit of simulation again turns to Customer.

- There is no set-up time.
- Item Packing time per customer is uniformly distributed; 20 to 30 seconds (Uniform(20,30))

3.1.5.2.2. Proposed RFID Check-Out Model

Customer arrival (AisleExit):

- Again, customer arrives randomly with inter-arrival time of 30 seconds. For this block, the negative exponential distribution is used, which is a probability distribution often applied in unpredictable arrival or service processes.
- Time till first customer is 10 seconds after the simulation begins.

Queue before RFID cashier (Queue_Cust):

- Queue capacity is 15 customers
- Queue discipline is First-in-First-out

RFID Cashier (RFIDCashier) product identification:

- No set-up time for the RFID cashier.
- Cycle-Time, that is, operation time per customer is 3 seconds.

Queue before Credit Card payment:

- Queue capacity is 15 customers
- Queue discipline is First in First out

Credit Card Reading/Payment (CCPayment):

- No set-up time for the Credit Card payment.
- Cycle-Time, that is, operation time per customer is 3 seconds.

3.1.5.3. Analysis and Comparison of Simulation Results: Models are run is run for 16 hours, simulating the 4 hour rush hours for 4 days. The reason to choose 4 days came out from trial-error runs to assess simulation output quality and consistency. There is a trade-off between data amount and output quality. The models gave unstable results for the first 3 hours, when it is tried with different seed numbers. But, after 3 hours, all models with different seeds gave similar stable results. They reached steady-state in terms of their output character. Even if the models are run for very long hours like 40 or 100 hours, this has only returned as long run times and data processing difficulties but with similar results. As a result, 16 hours are chosen as a result of trials. Summary reports for both models are given in Table 3.13 and Table 3.14.

Table 3.13. Summary Report for Classical Proposed RFID Check-Out Model

	Content		**Throughput**		**Stay time**
Block Name	**Current**	**Average**	**Input**	**Output**	**Average**
AisleExit	1	0.15	1656	1655	5.27
Cashier (Scan and Pay)	0	0.43	32780	32780	0.750
StoreExit	0	0.000	1638	0	0.000
Product	0	0.000	0	0	0.000
Queue_Cust	15	12.67	1655	1640	442.46
Unload	20	19.95	32800	32780	35.03
Queue_Items	0	4.05	32780	32780	7.12
Queue_PackIt	0	0.74	32780	32780	1.30
Pack	20	17.60	32780	32760	30.94
Run length	57600.00 (seconds)				
Seed number	2000				

Note that, on the above table, since every customer carries 20 items on the average, the numbers increase after Unload block; the unit of simulation object turns to items from customers. The first two columns show the remaining number of Customers/Items left in the blocks, at the end of simulation time. Throughput columns give the number of inputs and outputs of blocks in terms of customers or items. Stay time column shows the average waiting time in a block (i.e. operation).

Table 3.14. Summary Report for Proposed RFID Check-Out Model

	Content		Throughput		Stay time
Block Name	**Current**	**Average**	**Input**	**Output**	**Average**
AisleExit	0	0.000	1967	1967	0.000
RFIDCashier	1	0.10	1967	1966	3.000
StoreExit	0	0.000	1965	0	0.000
Product	0	0.000	0	0	0.000
Queue_Cust	0	0.006	1967	1967	0.18
CCPayment	1	0.17	1966	1965	5000
Queue_Payment	0	0.01	1966	1966	0.36
Run length	57600.00 (seconds)				
Seed number	2000				

The fundamental measures of the simulation runs are Statuses of the operator blocks throughout the simulation runs and the capacity loads and waiting times in the queues.

3.1.5.3.1. Simulation Results for Classical Check-Out Model: For the 15,16% of the time, customer feed to the system is blocked (see Figure 3.10), because subsequent customer queue (Queue_Cust) is occupied with the maximum number of customers. That is, Customers who saw the fully loaded queue, couldn't stand in line, they couldn't be served. This can be commented as loss of customer in the long run. As we all know from our daily lives, this is a very typical situation for a customer, shopping in a huge mall in rush hour.

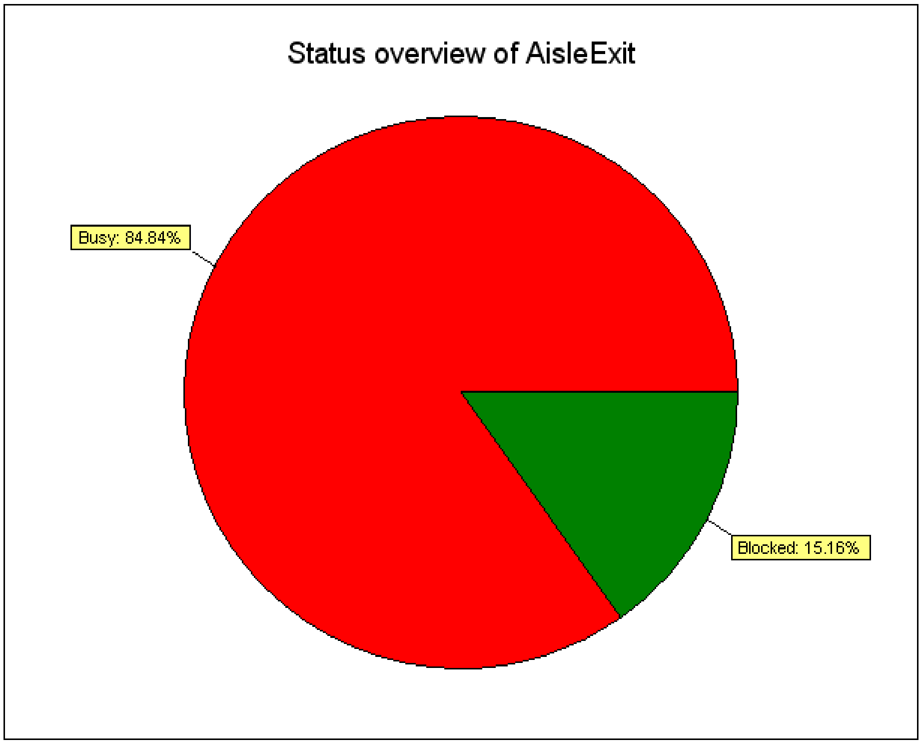

Figure 3.10. Status Overview of AisleExit – Model 1

In the Figure 3.11, depicting the status of the customer queue clearly implies that for the 99,33% of the time there is at least one customer waiting in the queue. This shows how excessively the human cashier is busy and the customers have to wait. In numbers, as shown in Summary Report of the model, the average waiting time is 442.46 seconds, i.e. more than 7 minutes.

Seven minutes of waiting in the queue is a usual average waiting time, as we know from our daily lives. This shows how the model is consistent to real life.

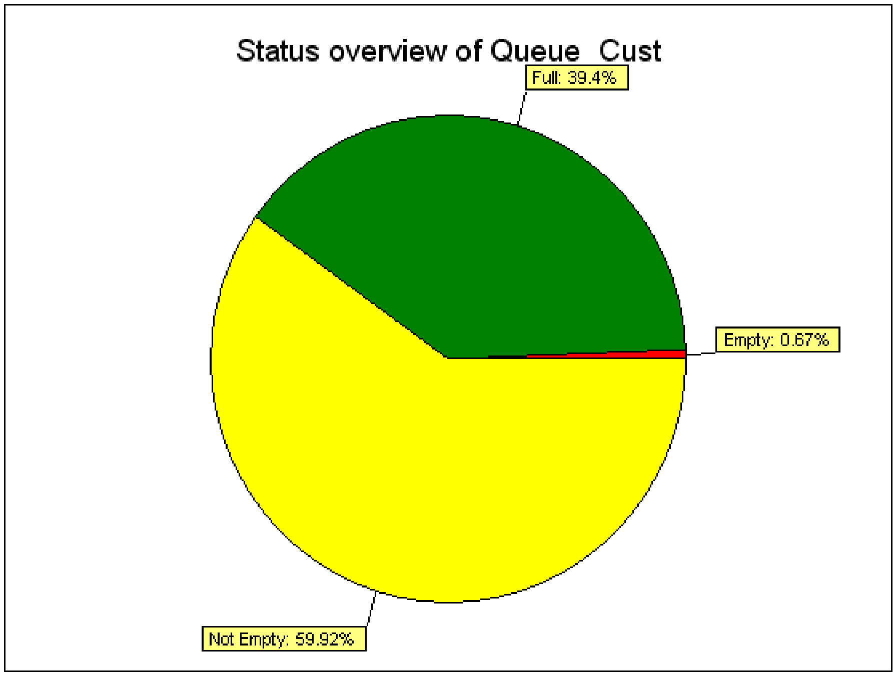

Figure 3.11. Status Overview of Queue_Cust – Model 1

Below, Figure 3.12 and Figure 3.13 imply the intensity of the queue busyness in terms of number of customers in the queue and the histogram of the customer load.

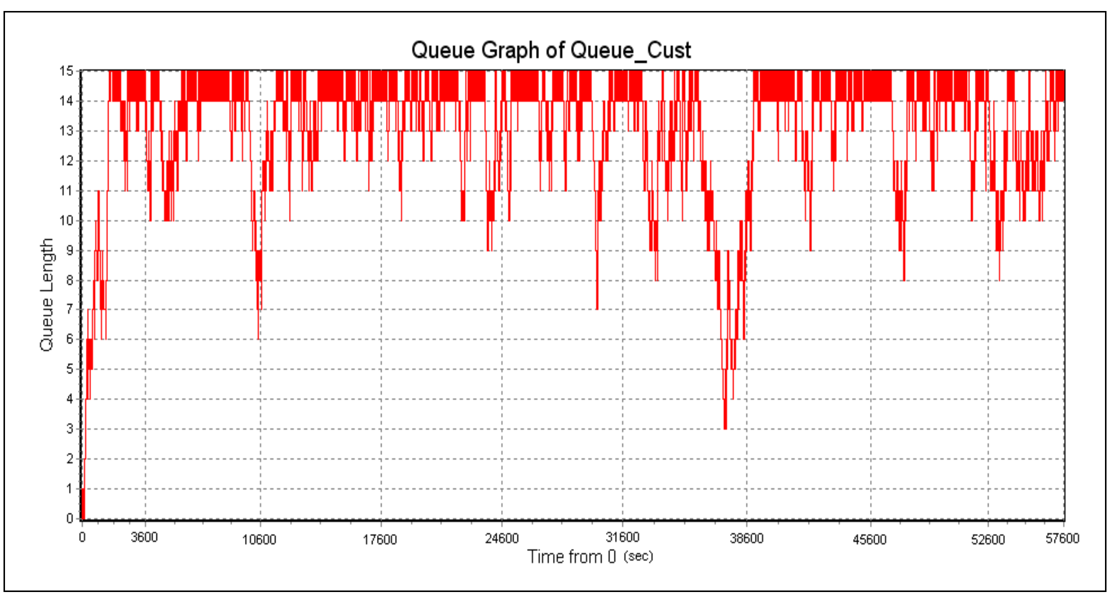

Figure 3.12. Queue Graph of Queue_Cust – Model 1

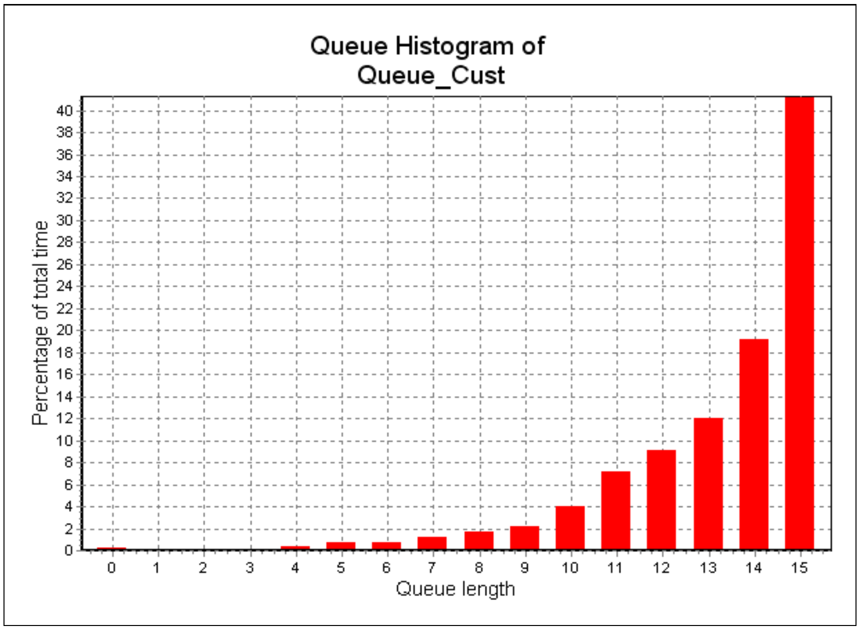

Figure 3.13. Queue Histogram of Queue_Cust – Model 1

In the Figure 3.14, the status of the Unloading operation can be seen. 99,74% of the time a customer is unloading the items to be bought. This situation clearly implies that there is an extensive load in unloading operation.

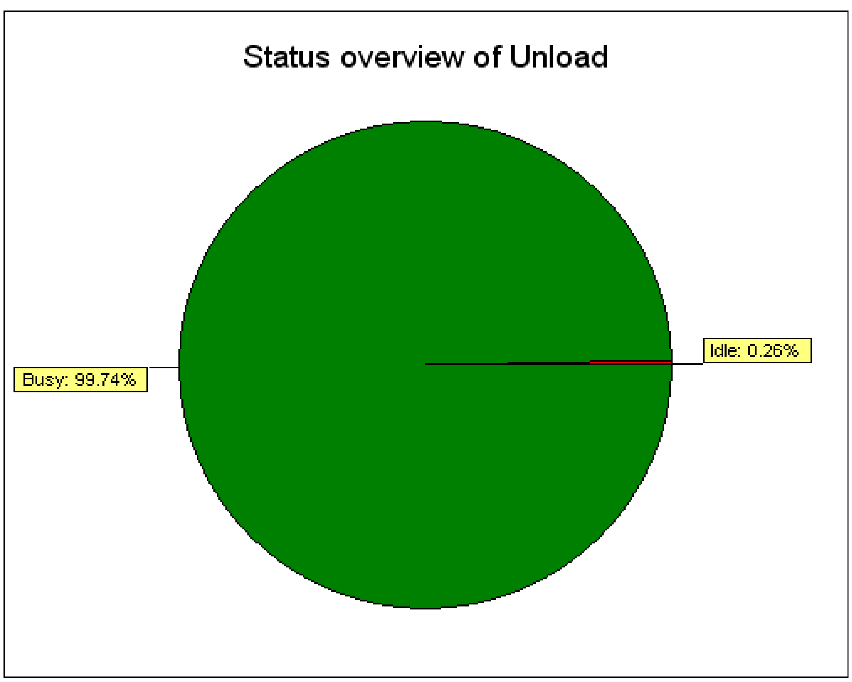

Figure 3.14. Status Overview of Unload – Model 1

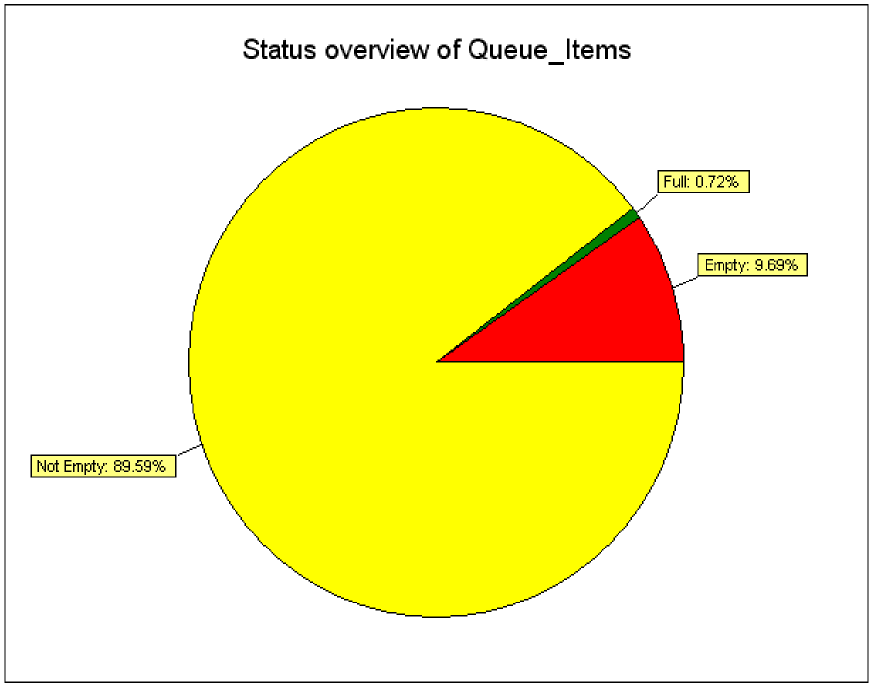

Figure 3.15. Status Overview of Queue – Model 1

For only the 9,69% of the time (see Figure 3.15), Items queue is empty. Again, the workload is intense. Figure 3.16 and Figure 3.17 imply the intensity of the queue busyness in terms of number of items in the queue and the histogram of the item load.

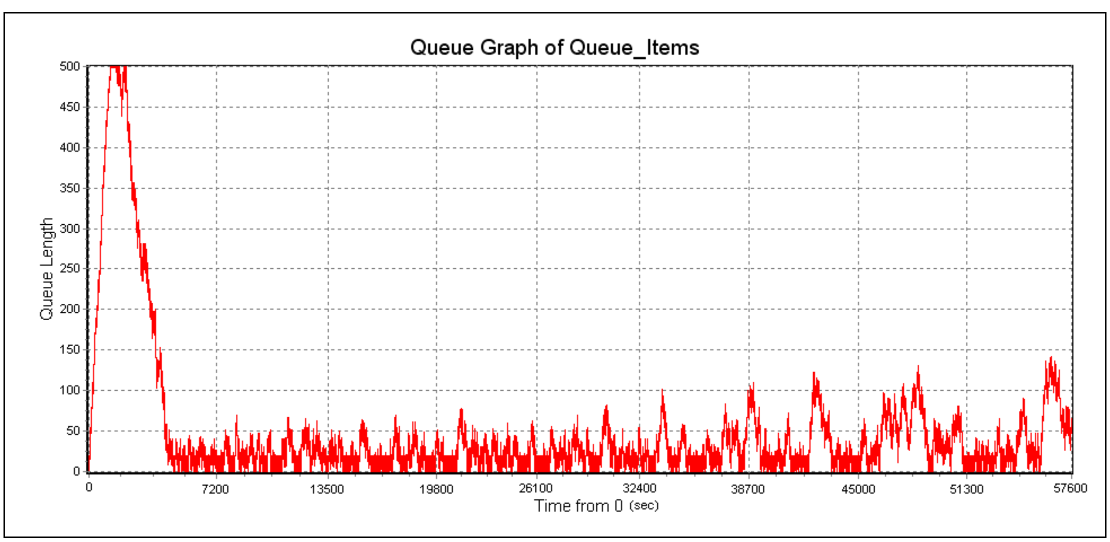

Figure 3.16. Queue Graph of Queue_Items – Model 1

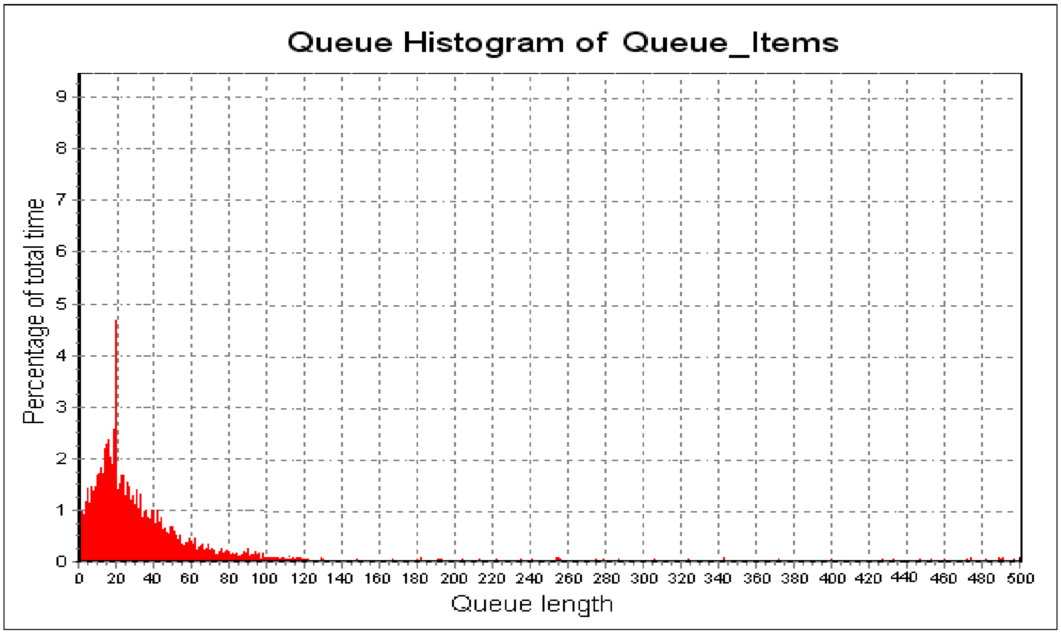

Figure 3.17. Queue Histogram of Queue_Items – Model 1

Parallel with the queue histogram above Human cashier is busy more than 89,71% of the time (see Figure 3.18).

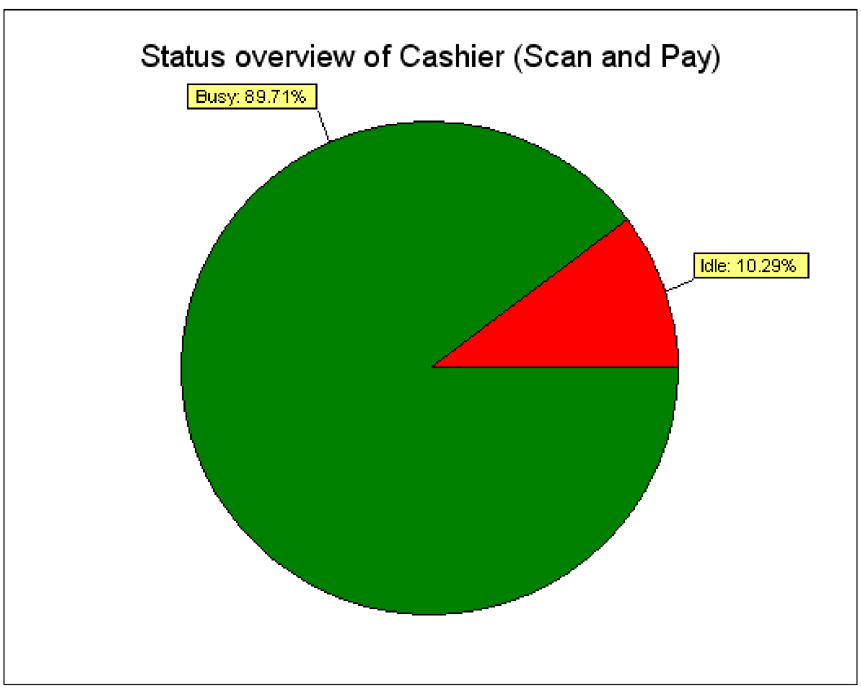

Figure 3.18. Status Overview of Human Cashier – Model 1

The following four figures (see Figure 3.19, Figure 3.20, Figure 3.21, and Figure 3.22) show statuses and queue loads of packing queue and packing operation.

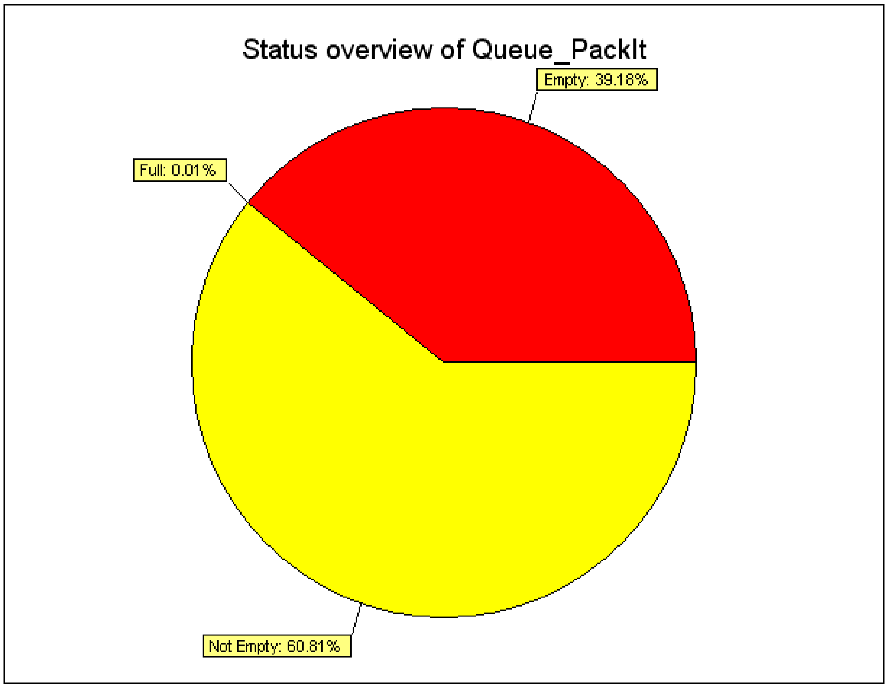

Figure 3.19. Status Overview of Queue_PackIt – Model 1

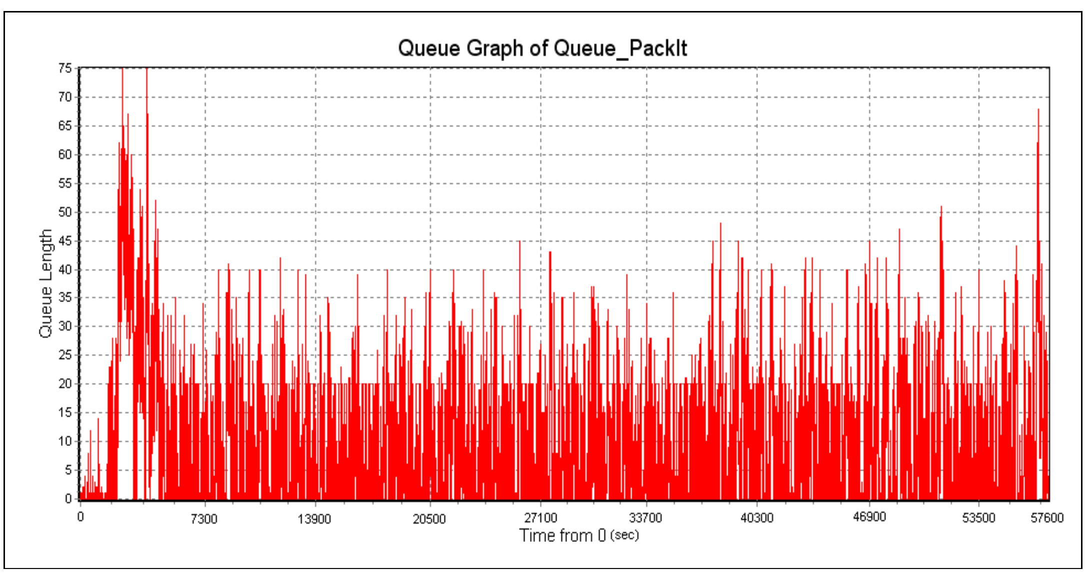

Figure 3.20. Queue Graph of Queue_PackIt

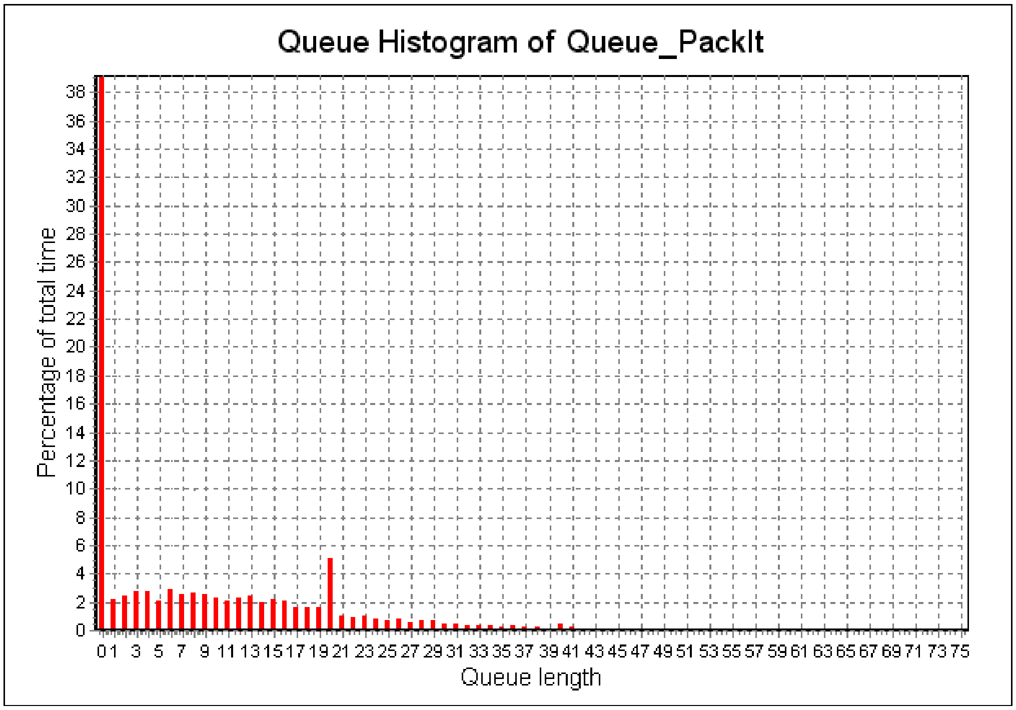

Figure 3.21. Queue Histogram of Queue_PackIt – Model 1

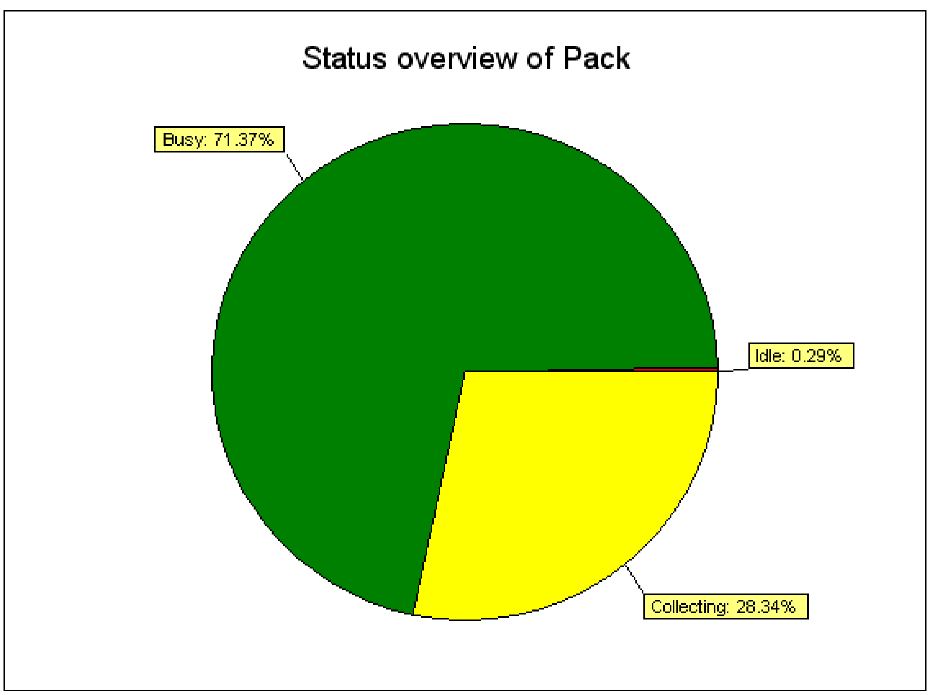

Figure 3.22. Status Overview of Pack – Model 1

3.1.5.3.2. Simulation Results for RFID Check-Out Model: Proposed system's simulation results are pretty promising in terms of waiting and operation times. Figure 3.23 shows that the source is 100% busy , that is, not like the classical payment method, there is no loss of customers. Source block, "AisleExit", has never been blocked. In the same conditions, this will return as customer and revenue gain, since the proposed system can reach higher number customer serving capacity.

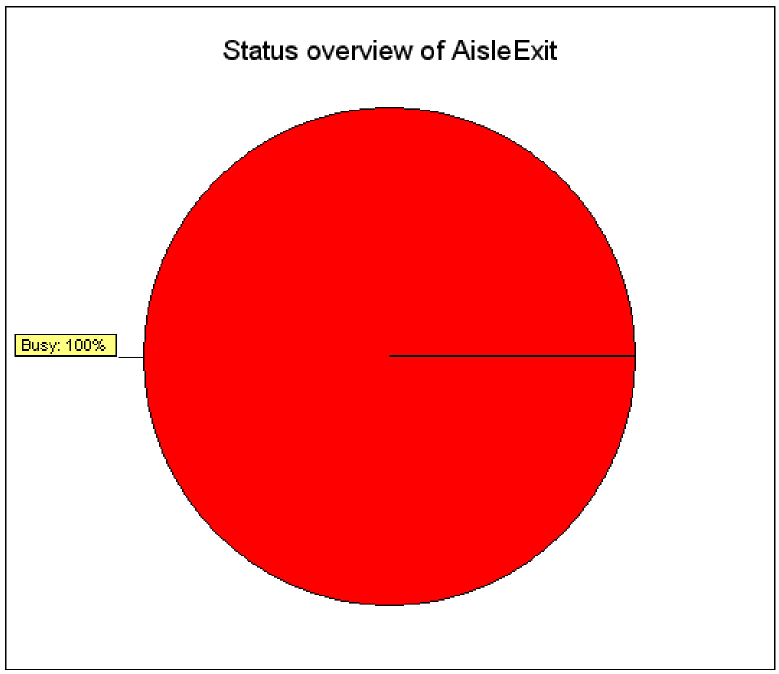

Figure 3.23. Status Overview Aisle_Exit – Model 2

In the Figure 3.24, depicting the status of the customer queue shows that only for the 21,03% of the time, at least one customer is waiting in the queue. This clearly implies that the RFID cashier tremendously shortens the waiting time of customers. This will return as customer satisfaction in the long run. In numbers, as shown in Summary Report of the model, the average waiting time is 0,18 seconds. Compared to 442.46 seconds of the classical payment, the improvement is extreme. But this is an expected situation because the customers will be just walking in the RFID check-out. There is no queue to wait and the operation time is only 3 seconds for a customer. The waiting time arises from the rush of customers to the tunnel and waiting for each other to pass through the RFID tunnel.

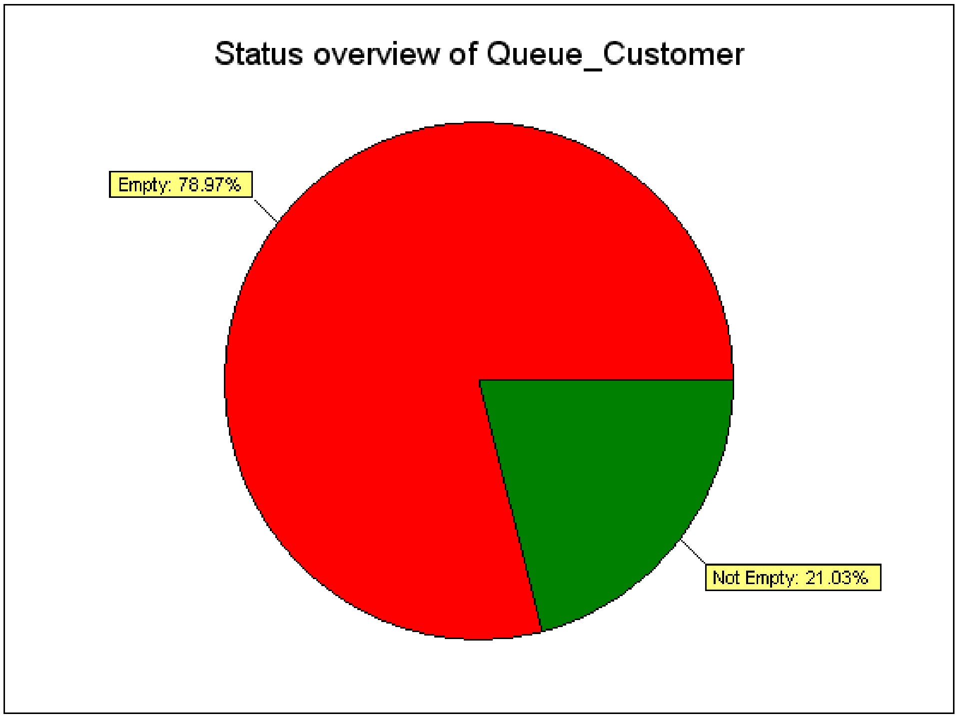

Figure 3.24. Status Overview Queue_Cust – Model 2

As can be seen on the Figure 3.25, the maximum number of customers in the queue is 10 and for the majority of the time queue does not contain any customers. Histogram (see Figure 3.26) of the queue implies this situation clearer.

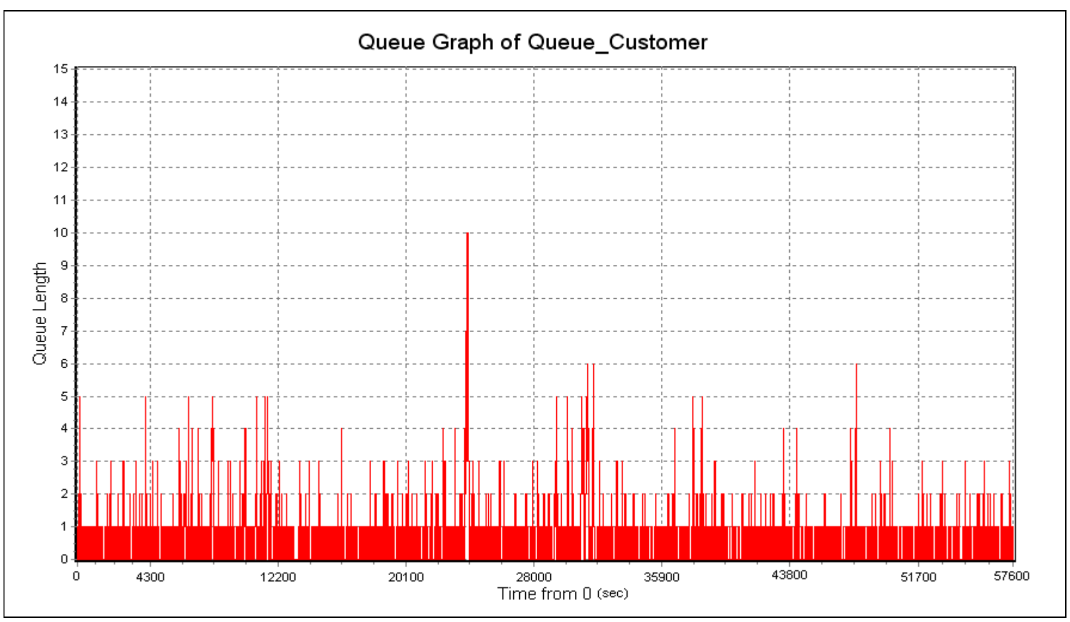

Figure 3.25. Queue Graph of Queue_Cust – Model 2

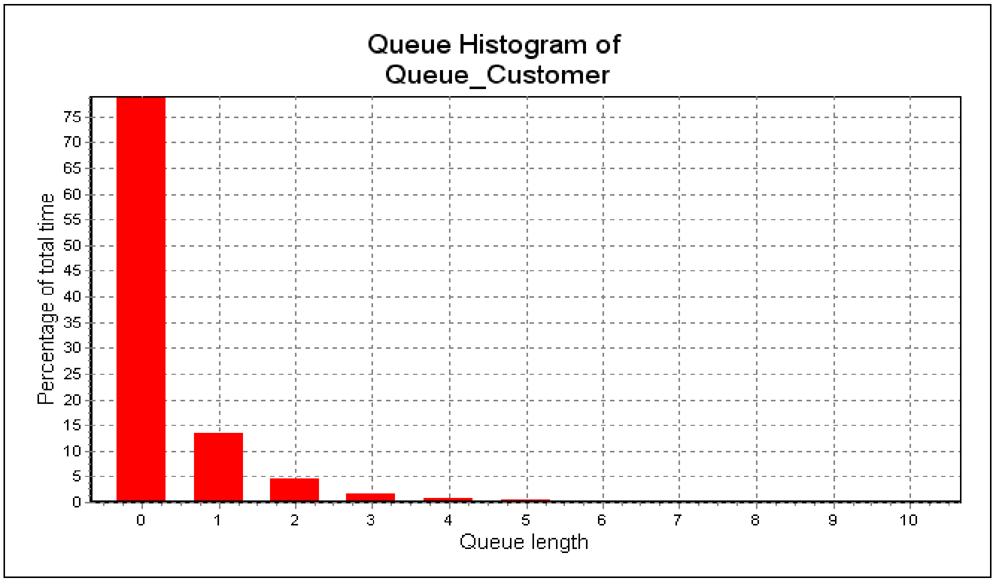

Figure 3.26. Queue Histogram of Queue_Cust – Model 2

Figure 3.27 shows, for only the 10,24% of the time, RFID cashier is busy. For the 89,67% of the time RFID cashier is expecting customers. Compared with human cashier busy 89,71% of the time, Capacity usage of the RFID cashier is pretty low. Much more number of customers can be served.

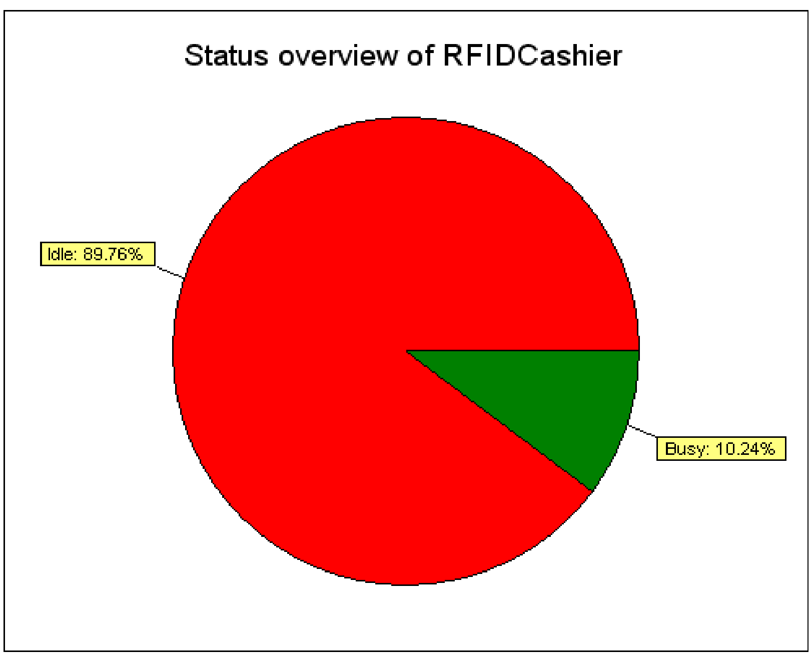

Figure 3.27. Status Overview of RFIDCashier – Model 2

The following four figures (see Figure 3.28, Figure 3.29, Figure 3.30 and Figure 3.31), show statuses and queue loads of payment queue and credit card payment operation. All the figures imply a comfortable check-out method is proposed, and proposed model can handle more number of customers, resulting with increased revenue.

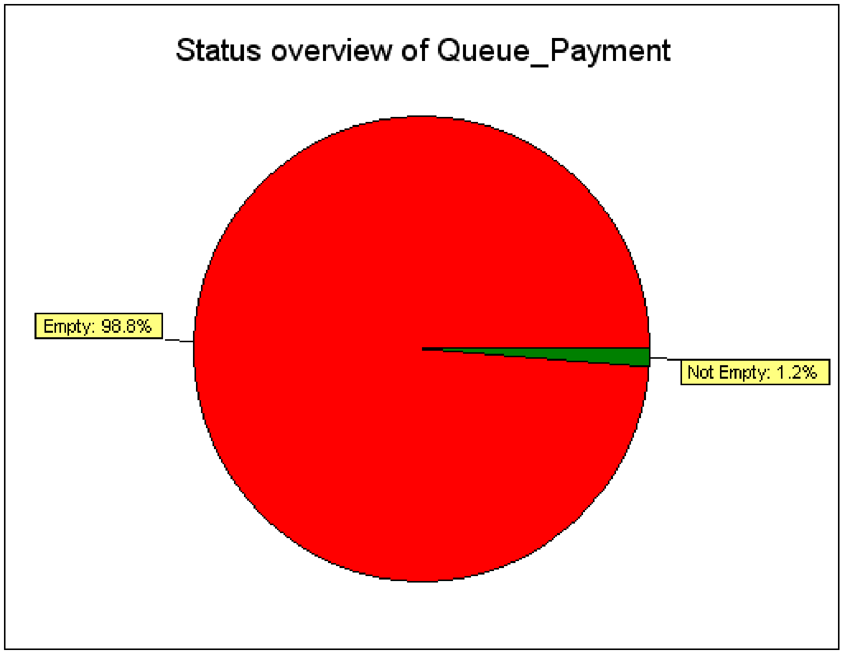

Figure 3.28. Status Overview of Queue_Payment – Model 2

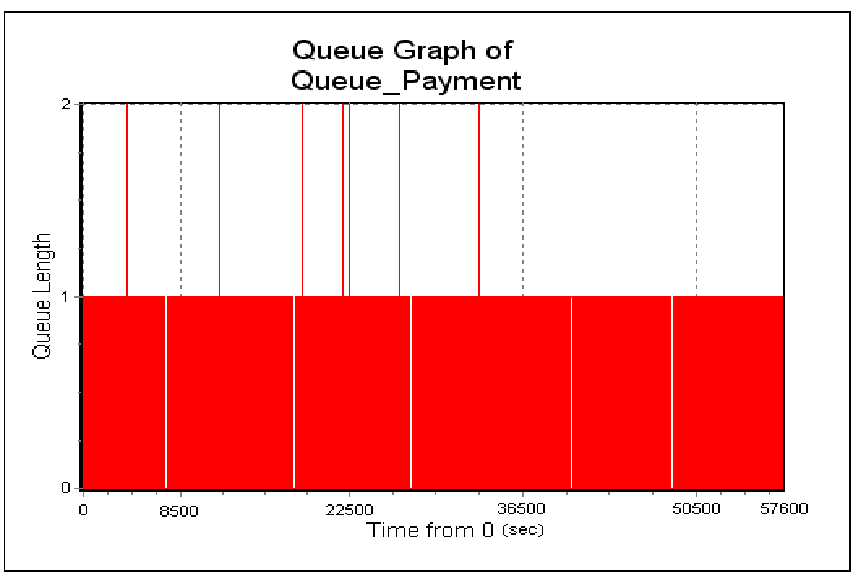

Figure 3.29. Queue Graph of Queue_Payment – Model 2

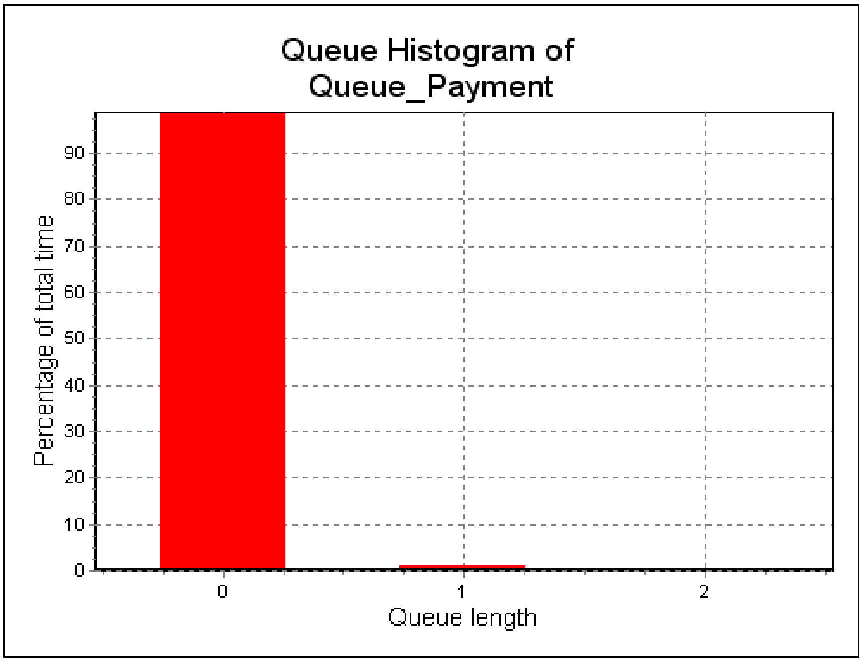

Figure 3.30. Queue Histogram of Queue_Payment – Model 2

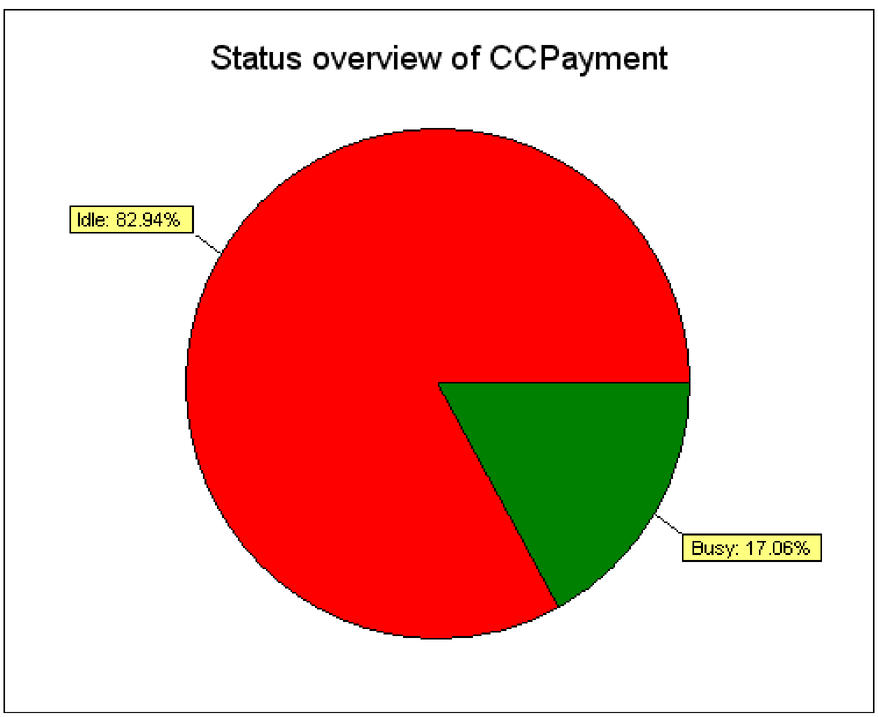

Figure 3.31. Status Overview CCPayment – Model 2

3.1.6. Current Similar Applications

3.1.6.1. METRO Group's "Future Store": The Metro Group is the world's fourth-largest retail and trading group in the world, with more than 2,300 store locations in 28 countries (mainly in Europe) and approximately 240,000 employees.

Metro's Future Store initiative is a cooperative project supported by many computing vendors, including IBM, Intel, and SAP. As part of the project, technologies and systems are invented, tested, debugged, and then showcased to the world of retailing [23].

At its RFID Innovation Center in Neuss, Germany, METRO Group has installed a self-checkout from NCR Corp. that reads RFID tags and bar codes. The NCR FastLane installed at the Innovation Center has an integrated RFID reader. Since both conventional barcodes and RFID tags are used, current implementation is described as "**hybrid**" self-checkout system. Additionally, instead of automatic reading the tagged items when customers are leaving the store, customer has to make the products by hand and one by one [23].

Vision of Future Store involves not only the payment but also to combine total product and inventory tracking with as much data as the individual consumer is willing to share with Metro, in the belief that the more Metro's system knows about you the shopper, the better—for both the shopper and for the company.

As the customer enter the store, he grabs a shopping carriage having the technologies WiFi, GPS, and RFID, all of which are built in.

After the customer identifies himself using a personal identification card on which a shopping list can be loaded. Customer can also load it into a PDA-like device attached to the handle. The PDA includes a flat-panel display that is attached near the handle so that the customer can interact with it as needed [23].

Since the cart is WiFi connected to both the store's internal computing system and the Internet, customer can build his own shopping list using data saved from your last shopping trips. For example, the system tracks what you commonly buy for weekly grocery items and will include them on the list automatically. Customer can then make additions and deletions. To maintain customer loyalty, the shopping cart will offer special discounts on items that it knows the customer have purchased in the past, or as rewards for being a frequent shopper.

If the customer’s refrigerator is RFID enabled, using the cart's WiFi connection to the Internet, customer can also check in with your refrigerator to see what is needed. If other parts of the customer’s living space are RFID enabled, he can check them, too.

Armed with the shopping list, the shopping cart operates somewhat like a mini-GPS system. The display gives a top-down map of the store aisles while it pinpoints the customer’s current location. If wanted, system will map out a route for the customer and highlight areas where the customer need to specifically visit. As the customer passes the cart by certain shelves, targeted advertisements for nearby products light up the PDA screen [23].

The store shelves are "smart shelves," meaning that they know exactly what products are on them and in what quantity. Before an item runs out on the shelf, the system has alerted the storage room and called for replenishing. The storage room is tightly tied system-wise to the supply chain and in-store inventory systems. As pallets are unloaded from a shipping truck, the contents of the entire pallet are instantly known (and accurately, without human inspection) and registered in the inventory system. When a shelf calls for a new carton of any product, as the product is passed through the doors of the back room and onto the store floor, the inventory system is updated and marked as "in store." Once placed on the shelf, the smart shelf updates the inventory as "on shelf." The product can be completely tracked by RFID technology from manufacturer, to store shelf, into a shopping cart, and finally to home [23].

By virtue of RFID-tagged products, the shopping cart knows exactly what is in it and can show you your local inventory neatly on the screen at all times perhaps sorted by product type, or alphabetically if wanted. As the shopping cart passes through a special gate at checkout, the RFID tagged items are instantly known to the in-store system. There is no need for the customer to line up and pile these items on to a checkout conveyor belt, only to have them individually scanned and re-handled back into the shopping cart. For non-RFID-tagged items, camera-enabled weight scales allow for automatic recognition of the customer's product selection. Advances in video capture and image analysis make this possible [23].

Company believes that, in the future, it might not even be necessary to pay interactively given that the customer is identified to the store, and perhaps customer's account will simply be debited [23].

The future plans of METRO group exactly intersect with the proposed self check-out system in this study.

3.1.6.2. FamilyMArt: FamilyMart, a Japanese retail chain owned by the corporate giant Itochu, has completed a two-phase pilot of an item-level RFID system at two of its busiest Tokyo stores. The project included tagging popular items to demonstrate how item-level tagging could speed the point-of-sale (POS) process and reduce queues during the busy early-morning and lunch rush hours [24].

FamilyMart operates 11,501 convenience stores in Asia, including more than 6,000 in Japan and 5,000 in such countries as Taiwan, South Korea and Thailand. By 2009, the retailer plans to open 250 stores in the United States. The two Tokyo locations involved in the RFID pilot had been experiencing heavy traffic and long queues at cash registers during busy hours. As part of the pilot, FamilyMart's suppliers hand-applied passive 13.56 MHz RFID tags to 500 of the retailer's most popular items. Each tag's unique ID number was associated with item-related data in the stores' back-end system [25].

The two participating stores were fitted with Toshiba TEC Express POS terminals with RFID interrogators, as well as related Toshiba TEC software able to interpret data from those readers. The Express POS platform employs RFID item-level tagging and contactless payment cards to make checkouts faster at busy convenience stores [25].

Company says the checkout processing is twice as fast and it now takes about 10 seconds for each customer. Even during the time when the store is very crowded, with this system, there are only about three people waiting in a line for the check-out [24].

3.1.7. Financial Assessment of the Proposed System

In this part of the study, a quantitative feasibility study, encompassing the costs and benefits of RFID technology, has been carried out to quantify the economical profitability of the implementation and to provide a justification for technology investments.

3.1.7.1. Costs and Benefits of RFID Deployment: Recently, the adoption of RFID technology and EPC standards for products identification, as well as of EPCglobal network for information management, is experiencing an increasing diffusion in the logistics pipeline, where they are expected to have a major impact on labor efficiency, processes automation and accuracy [11].

Scientific literature has widely debated the reasons and the current limits to RFID and EPC adoption, as well as related benefits on supply-chain processes. Jones et al. [12] argue that a main reason for RFID diffusion is the capability of tags to provide more information about products than traditional barcodes.

Manufacturing site, production lot, expiry date and components type are among information that can be stored into the tag chip. Moreover, tags do not need line-of- sight scanning to be read, since they act as passive tracking devices, broadcasting a radio frequency when they pass within yards of a reader [13] RFID tags also solve some of the inefficiencies associated with traditional barcodes.

For example, reading barcodes requires manual operations on packages, that is either the packages with barcodes or the reading devices should be manually handled to read the codes [14]. This may result in time consumption and difficult data capture if large amounts of goods have to be handled, such as in distribution centers or retail stores. In some cases, readability of barcodes can also be problematic, due to dirt and bending, bringing about reduced accuracy and low reading rate [15].

Prater et al. [17] have discussed the main benefits of RFID and of the EPCglobal network adoption for supply-chain processes, for the specific case of the grocery retailing. The availability of real-time information is regarded as the main benefit, although additional outcomes can be found in increased inventory visibility, stock-out reduction, real-time access and update of current store inventory levels, automated proof of delivery, availability of accurate points of sale data, reduction of labor associated with performing inventory counts of shelved goods, improved theft prevention and shrinkage, and better control of the whole supply chain [16]. For the model studied here, labor reduction and theft prevention applies suitably.

Despite the achievable benefits, several authors agree that the main limit to a wide use of RFID technology has to be found in its cost [17, 18].

Consequently, critics to RFID argue that investments in tags and readers, as well as in the related informatics infrastructure, are still not profitable. Nonetheless, quantitative feasibility studies about the economic profitability of RFID and EPC implementation still lack in literature.

To this extent, cost/benefit justification is a major barrier to the adoption of RFID and EPC, concluding that future research should investigate how to best implement these technologies in the grocery industry.

In the section of the study, a feasibility study is conducted for the proposed system.

Prior to assessment, the benefit and cost items for the proposed system must be listed. For this study, based on the system defined and designed, benefits and costs can be grouped under six items (see Table 3.15):

Table 3.15. Benefit and Cost Items

Benefit and Cost Items	Remarks
Benefit item 1	Includes Reduced Labor cost
Benefit item 2	Increased Payment Processing efficiency (i.e. Increased sales and customer satisfaction – Reduced Errors etc.)
Benefit item 3	Decreased theft
Cost item 1	Reader gates, printers and other infrastructure
Cost item 2	Software and consulting of Project
Cost item 3	Tagging and maintenance

<u>3.1.7.2. Financial Assessment:</u> Business case in this study involves implementation of RFID self checkout project in a store having 20 human cashier. Financial metrics [20] are quantified over a 5-year period and considering a 5% interest rate. High inflation rate in our country is not considered to make the assessment simpler and Euro is used as the currency. As mentioned, they mainly encompass RFID equipments, such as tags, readers, fixed and mobile devices, and related software, up to the implementation project unitary costs, shown in Table 3.16, have been derived from literature, market prices, catalogues of RFID equipment producers and vendors [19]. The annual revenue of the store is assumed to be € 15.000.000 and annual profit is € 3.000.000 [10]. Monthly salary of a worker is € 500. Two security employees are eliminated and two new employees will be assigned for tagging items. Total number of tagged products is estimated to be 1,000,000.

The numbers for the hardware, software, consulting and tag costs can be seen in Table 3.16.

Table 3.16. Costs of RFID Equipments

Hardware and software RFID equipments	Costs
RFID tag UHF low quantity (€/tag)	€ 0,15
Printer of labels (€/printer)	€ 2.500
RFID gate (€/gate)	€ 2.500
Software and implementation project	€ 200.000

According to RFID Journal Live Europe [21], theft and shrinkage prevention can amount 15% of total sales. In this study, a pessimistic approach is taken, and benefit caused by decreased theft is assumed to be only 0,5% of sales.

Increase in sales can be 3% pessimistically. Many references assume much higher benefits.

Prior to the calculations of these metrics, monetary provisions of the Cost/Benefit items should be figured in. Details of the mentioned ones and the other cost and benefit items are given in Table 3.17 and Table 3.18. On the next pages, the results, according to these numbers are given.

Table 3.17. Annual Benefits of RFID Deployment

		Annual Cost Per Item	# of Items	Annual Subtotals	Annual Totals
Benefit item 1	Cost of 40 Human cashiers *	€ 6.000	20	€ 120.000	
	Cost of 2 Security employees *	€ 6.000	2	€ 12.000	€ 132.000

		Revenue / Profit	Benefit %	Annual Subtotals	Annual Totals
Benefit item 2	Increased Efficiency in Payment Processing (3% of the annual profit)	€ 3.000.000	3	€ 90.000	€ 90.000
Benefit item 3	Decreased Theft (0,5% of the annual Revenue)	€ 15.000.000	0,5	€ 75.000	€ 75.000

*Monthly salary of a worker is € 500.

Table 3.18. Annual Costs of RFID Deployment

		Annual Cost Per Item	# of Items	Annual Subtotals	Annual Totals
Cost item 1 **	Cost of 40 RFID cashiers (Tunnels)	€ 2.500	20	€ 50.000	
	Cost of 2 RFID printers	€ 2.500	2	€ 5.000	
	Cost of 2 employees for tag printing/sticking *	€ 6.000	2	€ 12.000	
	Other hardware and Infrastructure			€ 40.000	€ 107.000
Cost item 2	RFID software and Consulting ***			€ 200.000	€ 200.000
Cost item 3	Tags	€ 0,15	1.000.000	€ 150.000	
	Maintenance			€ 20.000	€ 170.000

*Monthly salary of a worker is € 500.
** Except 2 employees, only for the first year of deployment
*** Only for the first year of deployment

Standard financial metrics are used for assessment [20]. These are:

- Net cash flow
- Cumulative Cash flow
- Payback Period
- Return on Investment (ROI)
- Internal Rate of Return
- Net present value (NPV)

According to the mentioned numbers in Table 3.17 and Table 3.18, calculations are made. Results can be seen in Table 3.19, Figure 3.32, Figure 3.33, Table 3.20, Table 3.21 Table 3.22, and Table 3.23. Note that all numbers are given in € 1000 units.

Table 3.19. Net Cash Flow

	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
Cash Inflows / Benefits and Gains		`				
Benefit item 1	132	132	132	132	132	660
Benefit item 2	90	90	90	90	90	450
Benefit item 3	75	75	75	75	75	375
Total cash inflows	297	297	297	297	297	1.485
Cash Outflows / Costs & Expenses						
Cost item 1	-107	-6	-6	-6	-6	-131
Cost item 2	-200					-200
Cost item 3	-170	-170	-170	-170	-170	-850
Total cash outflows	-477	-176	-176	-176	-176	-1.181
Cash Flow Summary						
Total inflows	297	297	297	297	297	1485
Total outflows	-477	-176	-176	-176	-176	-1181
Net cash flow	-180	121	121	121	121	304

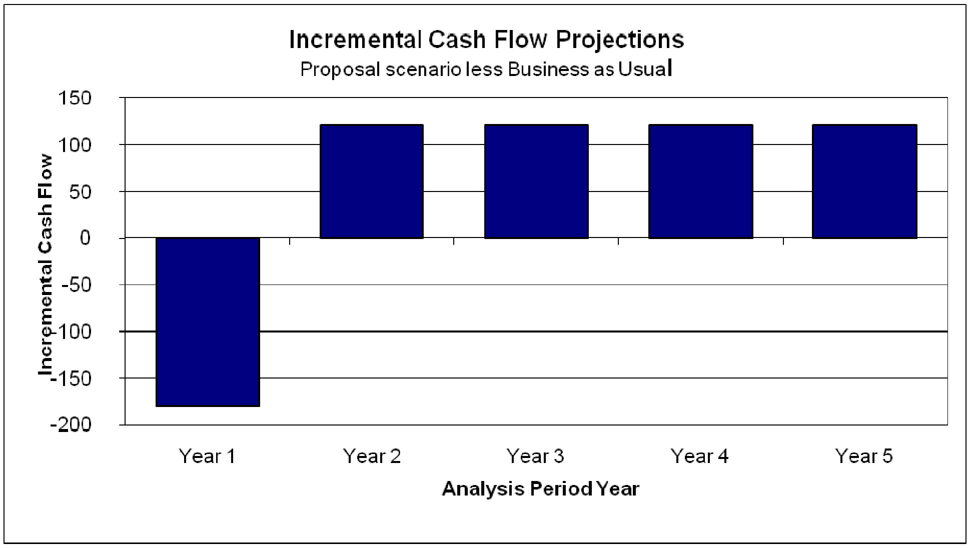

Figure 3.32. Graph of Net Cash Flow for Analysis Period

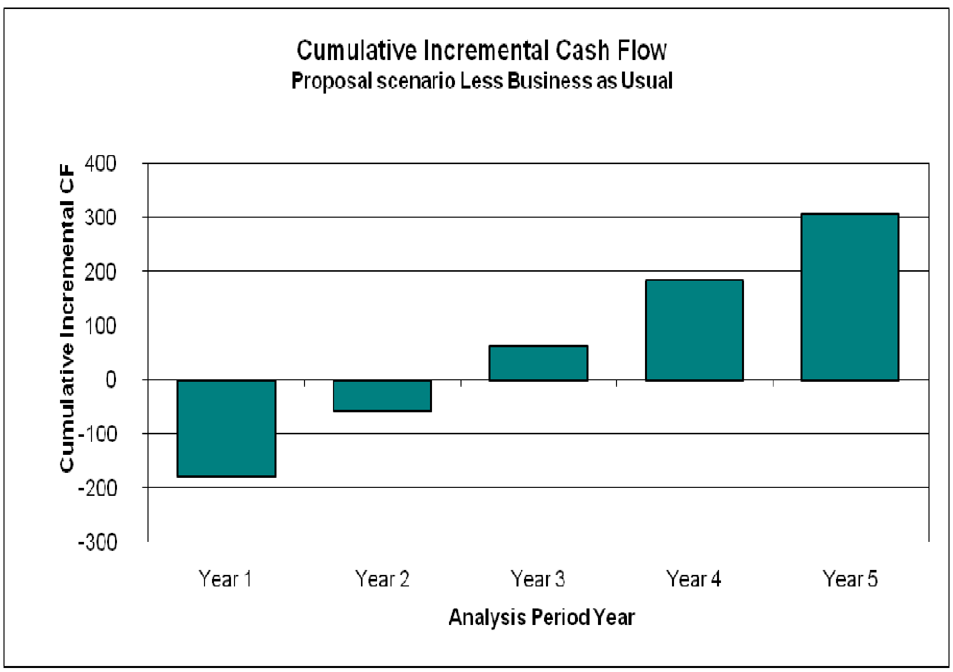

Figure 3.33. Graph of Cumulative Cash Flow for Analysis Period

Table 3.20. Payback Period

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Total incremental inflows	297	297	297	297	297	1.485
Total incremental outflows	-477	-176	-176	-176	-176	-1.181
Net incremental cash flow	-180	121	121	121	121	304
Cumulative Incremental Cash Flow	-180	-59	62	183	304	
Payback Period:	2,5	Years				

Table 3.21. Return on Investment

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Total incremental inflows	297	297	297	297	297	1.485
Total incremental outflows	-477	-176	-176	-176	-176	-1.181
7,5%	**Simple ROI, 3 years**					
18,2%	**Simple ROI, 4 years**					
25,7%	**Simple ROI, 5 years**					

Table 3.22. Internal Rate of Return

Initial guess for the IRR (0% - 100%) : 5,0%

Year 1	Year 2	Year 3	Year 4	Year 5	Total
-180	121	121	121	121	304

Internal Rate of Return (IRR) 55,8%

Table 3.23. Net Present Value

Interest rate for discounting (0 - 100%) 5,0%

Year 1	Year 2	Year 3	Year 4	Year 5	Total
-180	121	121	121	121	304

Discounting at Year End:
Discounted Cash Flow Stream

					NPV
-171	110	105	100	95	237

Discounting at Mid-Year
Discounted Cash Flow Stream

					NPV
-176	112	107	102	97	243

3.1.7.3. Analysis of the Results: The most critical financial measure, Payback Period, shows that RFID deployment will pay-off itself after 2,5 years.

Investors will gain positive number that is benefits, after 2 years, according to the net and cumulative cash flows. Additionally, positive Return on Investment is achieved. But, for the first year of deployment, company must bear high burden of the investment (€477.000) and net cash outflow (€180.000). Starting with the second year, benefits will pay off the costs and at the middle of the third year, benefits will totally pay off the costs. Internal rate of return (55,8%) is seriously high compared to 5% IRR.

According to the financial metrics, in the long run, the company will gain high benefits by deploying RFID, but the financial metrics in this study are based on assumptions at some points. More precise numbers will help the actual investors to make the metrics healthier. But, the whole analysis in the study, except the actual numbers for some cost/benefit items, will form the basis for financial assessment and decision making.

Finally, it can be concluded that RFID deployment with the proposed model is feasible. But we have to note that, case-based analysis on a different business case can give different results. Additionally, feasibility of the model is sensitive to annual revenue and to the profit of the store. Another sensitivity factor is the number of human cashiers. Only for a relatively "large" (i.e.40 cashiers and millions of Euros revenue and profit) store with high business volume, this model can be feasible.

3.2. RFID Based Employee Control System

3.2.1. Introduction

In the modern service society people work in networks with several participants at located at various places. Working in changing cooperative relationships is becoming one of the essential features of modern work organization.

As a result, for the last ten years, driven primarily by cost reduction goals, interest in and implementation of what has become known as "alternative officing" (AO) [26] have grown enormously. The traditional idea of work is supplemented or replaced by modern concepts. One of the newest concept is desk sharing in "Non-Territorial Offices".

The number of companies with employees working outside the office is growing day by day. Employees such as field sales staff, management consultants and tax auditors spend considerable time out of the office. When employees go to the office, they need somewhere to work. Thus arose the idea of the non territorial office where employees do not have a workstation but are assigned one when they arrive there [26, 31].

This new concept involves highly functional tables and customized lay-outs serving both as a power source and as a support for a range of accessories, includes elements necessary for providing optimum access for electrical devices, computer screens, trays, shelves, lamps etc. Thus, this new concept can adapt itself to the needs of each company and employees.

This part of the study focuses on smart, secure and efficient control system design to manage "Non-Territorial Officing" using RFID technology.

3.2.2. General Definitions

3.2.2.1. Types of AO's: Since 1988, large industrial corporations and firms as diverse as IBM, Citibank, Andersen Consulting, Monsanto and Alcoa have, through some form of AO, rather dramatically changed the way they allocate and design space.

AO typically involves 5 (often overlapping) types of 'alternative' workplace solutions [27]; "Universal plan offices/workstations" imply a small office facility with similar attribute to the main office, for employees who work nearby to work during traffic peaks or for more substantial period of time. "Non-territorial/unassigned offices/workstations" means a space allocation program that does not permanently assign desks or workstations to specific individuals. Examples include hotelling, free addressing, and shared offices. "Home-based telecommuting" is a program that allows staff to work at home during normal business hours for the majority of the time. "Team/collaborative environments" is a flexible work area designed to support work teams as they expand or shrink. Examples include activity centers, project areas, brainstorming areas. "Virtual officing" implies the use of portable computers with modems and faxes, portable printer, cell phone , and PDA to conduct work any time anywhere in non-traditional office settings (customer's offices, airline clubs, airplanes, hotels, etc.).

3.2.2.2. Non-Territorial (Unassigned) Offices: For types of work like field sales, customer support, management consultancy, tax auditing and project management, all of which require the employee to be frequently out of the office, non-territorial or unassigned offices have become a common alternative to more traditional assigned workstations and offices [26]. Widely known as 'hoteling' (from the concept of calling in advance to reserve a space, just like one does in a hotel), individuals use any one of many workstations designated for this population of nomads either on a first come, first served basis, or by reserving an office or workstation in advance. These highly mobile employees do not have their own permanently assigned office or workstation. They sit in different workstations on different days, or even at different times of the same day if they leave the office for a significant period of time.

Dozens of variations on this theme exist, from very small drop-in spaces like carrels in a library to open and closed offices of varying sizes. Reservation systems range from electronic to manual (a secretary records who will be in or out of the office), or individuals can just ‘take a chance’ on a first come, first served basis. The designated pool of unassigned workstations may be for one’s work group or department (‘group address’) or for anyone in the building or company (‘free address’). Unassigned non-territorial offices are also frequently combined with the activity-setting concept noted above, so that when in the office, one can choose to work where it makes most sense for a particular activity. The primary advantage to the organization of unassigned offices (and their staff–workstation ratios of from 3:1 to 7:1 or higher) is reduced real estate (and thus cost) requirements ranging from 20 per cent to 30 per cent or more [28].

Some forms of AO, notably non-territorial offices, are in fact a form of infrastructure on-demand. Unlike conventional office allocation, in which each person has their own assigned office or workstation, and therefore any growth in employee population requires physically adding new workstations or offices, non-territorial space accommodates such growth seamlessly, simply by changing the ratio of workers to office spaces. It is an example of achieving infrastructure on-demand through administrative policy rather than through physical construction of some kind [26].

Figure 3.34. A Typical Unassigned Office [29]

3.2.3. Problem Definition

Today almost every company uses control systems to manage its most valuable asset, human resource, and secure the workplace with its all contents including people and other assets. While with these general concerns, companies need to present this officing service with low cost [26].

Non-territorial office is a need of today's companies as a low cost solution for officing. But, especially in global or multi-location companies with a lot workers in different departments and divisions in different buildings/facilities, these requirements leads to very complex system of employees and locations. Addition of alternative officing styles like "Non-territorial offices" to multi-locations, management of the building and employees turns to a complex problem, which cannot be handled with classic methods like electronic personnel identification cards and their readers put in the entrance of the building.

Since no any specific worker is the owner of the workplaces in Non-territorial offices, with classical systems, security and privacy concerns become serious problems. An employee cannot be assigned to a specific location in this new style of officing, so the current user of the workplace cannot be known with classical control systems. This is a clearly a security risk for the company [30].

Other than security, accessibility and attendance of the employee is another problem. Users of the building change in time basis, not location. When an employee is needed by the management, the manager may only meet empty seats and will not be aware whether he is at work in another location or the employee is not in any of the company facilities. Additionally, a general view of the employee attendance will not be available with the classical technologies.

3.2.4. Solution Proposal

While using anonymous offices as a low cost solution, security of the workplace and the efficient management of the human resource can be maintained using RFID technology. RFID is directly applicable to managing the humans within the facility and with careful thinking, is capable of providing facility managers with meaningful data. At checkpoints, identification can help detect and interdict undesirable entrants.

When examined carefully, office/building management systems involve many numbers of sub-systems like (a) Human Identification system, (b) Access Control systems and (c) Personnel tracking systems. All of the systems above can be implemented efficiently using RFID technology [30].

The solution to the defined problem can be solved by narrowing the identification, access control and employee tracking issues to room and employee level.

The designed control system in the next pages involves RFID chipped personnel card and a laptop, RFID readers in and outside of the office rooms, RFID reader antenna for the anonymous tables. An integrated reporting system to locate the employee real time and determine the general attendance of the worker in given time period is included in the control system.

As a result a tighter security will maintained with the high accessibility of the employee in a low cost office. Additionally, attendance reports from an individual employee to a facility basis can be created.

Since the offices are used commonly by many employees, the problem of workplace assignment must be narrowed down to room and employee level. Additionally, the employees must be reachable within the buildings of the company. That is, any employee must be traced to be reached within different facilities.

3.2.5. Proposed System Design

3.2.5.1. Elements of the system: The proposed system consists of elements listed below. They are divided into 3 logical groups. These groups and items included in them are listed below:

Employee

- RFID card: Keeps employee identification data

- Laptop: Employee's laptop has an RFID tag. This tag can be identified with the antennas close to table when the employee occupies it.

Office

- RFID Tag readers on door: Reads the Employee ID data on the RFID tag. Two readers are attached for every office room. One is located outside of the office to determine entrances into the office and the other is located inside to determine exits from the room.
- RFID Tag reader Antenna: Reads the Employee ID data on the chipped employee‘s laptop. Via antenna, the employee is located at the table he occupies. As a result, table occupation data is extracted and conveyed on the tracking screen. Additionally internet connection and telephone service is turned on.
- Human resources (HR) server: Server keeps Employee location and attendance data as well as other statistical data. Additionally it makes relevant calculations and directs data flow between the components of the system. Reporting functions and data signals transported to the Internet connection and telephone central through the server. A database is kept on this server for employees, current locations and also historical data.
- Employee tracking screen: Managerial interface for tracking and reporting functions.

Other Building Facilities

- Internet Connection center: According to the table occupation with specific Employee ID, internet connection port is opened and relevant authorizations are given.
- Telephone Central: According to the table occupation with specific Employee ID, Telephone on table is assigned to the employee.

<u>3.2.5.2. Physical Structure of the Office and Process Flow Chart:</u> Physical structure of the office and the building is shown in Figure 3.35, below.

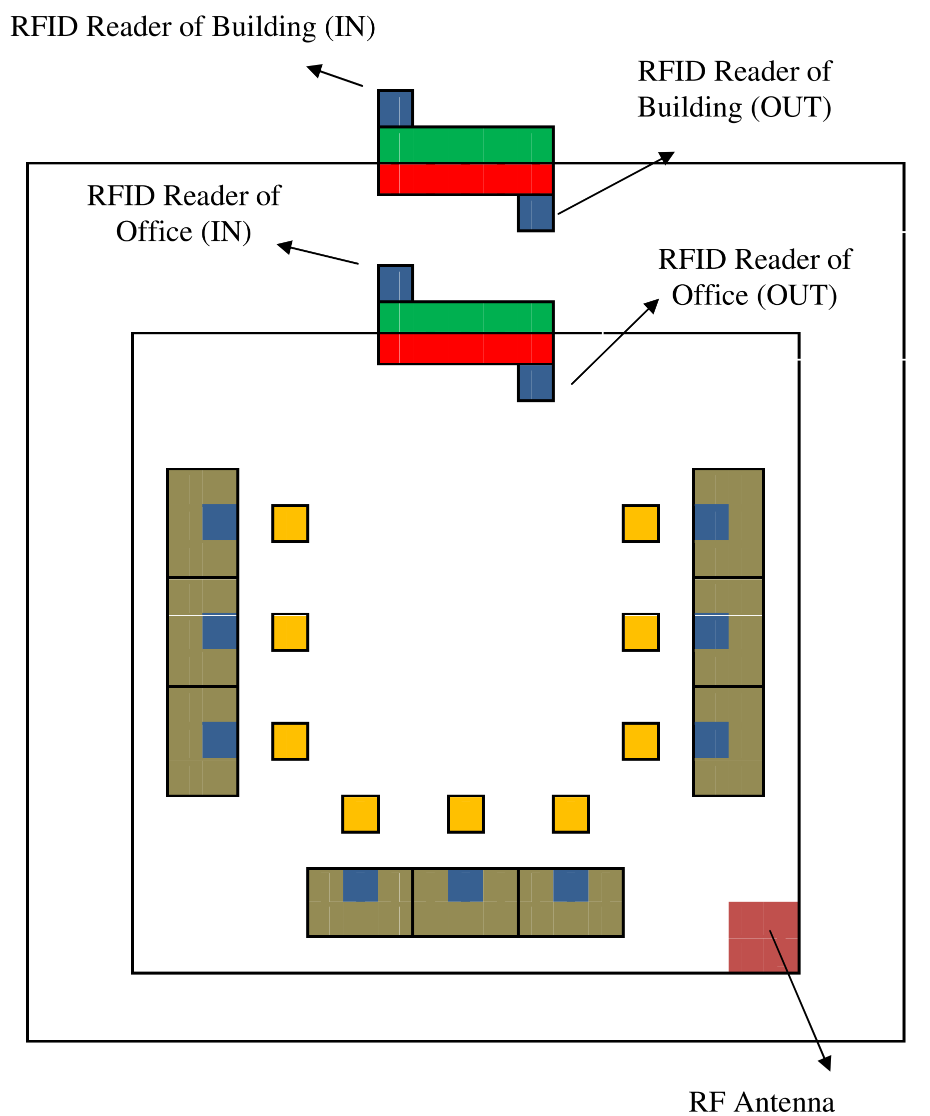

Figure 3.35. Sketch of Physical Structure of the Proposed Building and Office

The general process flow is demonstrated on and Figure 3.36.

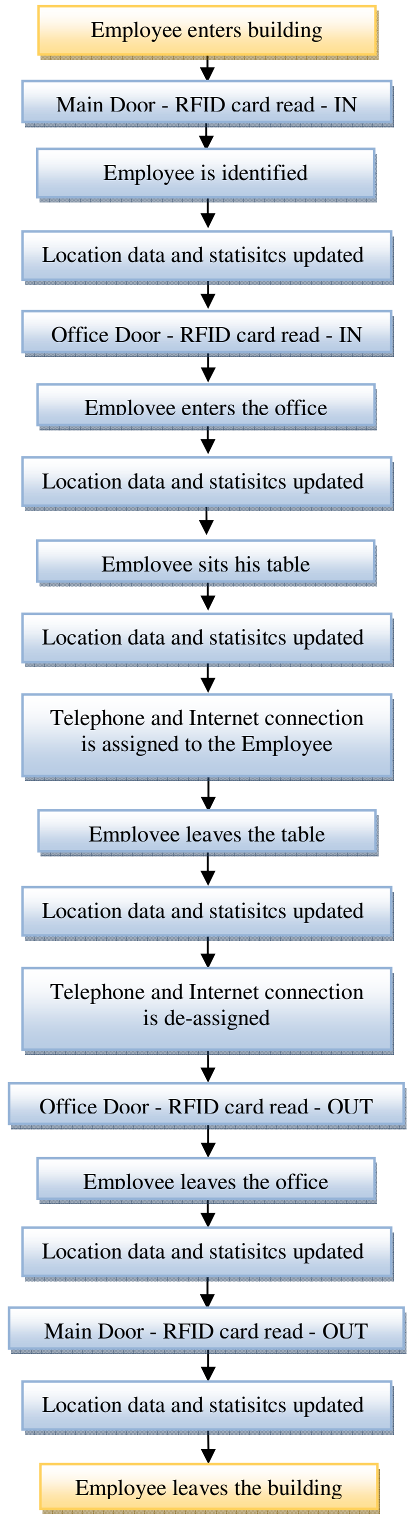

Figure 3.36. General Process Flow – RFID Employee Control Model

3.2.5.3. Inputs for the system: Other than the elements of the system, database tables on the servers keep employee, locations, plants/locations, company and reader data. In addition to these, dynamic data like current employee status (inside or outside of the company locations), current employee location is fed into the system.

3.2.5.4. Outputs of the system: According to the employee actions, the system is updated, statistical and dynamic location data is formed and screened via the employee tracker screen and reports. The formats of the reports are given in Figure 3.37, Figure 3.38, Figure 3.39 and Figure 3.40.

3.2.5.5. Database Tables for the Proposed System: The proposed system's database table structure includes related data and is structures. Formats are given in following tables.

Table 3.24. Employees Database Table

Employees
Employee ID
Employee Name
Company ID
Department ID
PartFullTime Indicator

Table 3.25. Door_Reader Database Table

Door_Reader
Door Reader ID
Door Character (IN or OUT)
Plant ID
Floor
Office No

Table 3.26. Table_Reader Database Table

Table_Reader
Table Reader ID
Table Number
Telephone number
Internet Port number

Table 3.27. Plants Database Table

Plants
Plant ID
Plant Name

Table 3.28. Companies Database Table

Companies
Company ID
Company Name

Table 3.29. Departments Database Table

Departments
Department ID
Department Name

The result of data collecting and processing on the server, the query table below is formed. Date and time data are taken into table dynamically. Every action is numbered and given an automatic number.

Table 3.30. Employe_Tracks Database Table

Employee_Tracks
Action ID
Employee ID
Employee Name
PartFullTime Indicator
Employee Status (IN or OUT) (*Current*)
Duration
Plant ID (*Current*)
Plant Name (*Current*)
Company ID
Company Name
Department ID
Department Name
Floor (*Current*)
Office No (*Current*)
Table Number (*Current*)
Telephone number (*Current*)
Internet Port Number (*Current*)
Employee Action Date (*Last*)
Employee Action Time (*Last*)

3.2.5.6. Report Screens (Output): Two types of reports are designed as the output of the system. The details are given in the next sections.

3.2.5.6.1. Real-Time Employee Tracker: This report provides real-time location and status (whether an employee is IN or OUT of the any plants of the Multi location company) for a specific employee.

The main screen of the reporting facility to input search criteria and the Real-time employee data is given below:

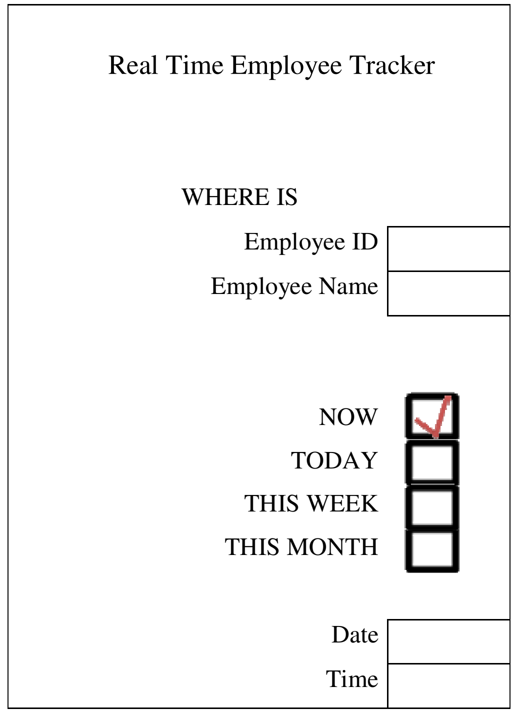

Figure 3.37. Sketch of Main Screen of Employee Tracker

After executing the program with the criteria given above, the resultant real-time employee data is screened in the format below:

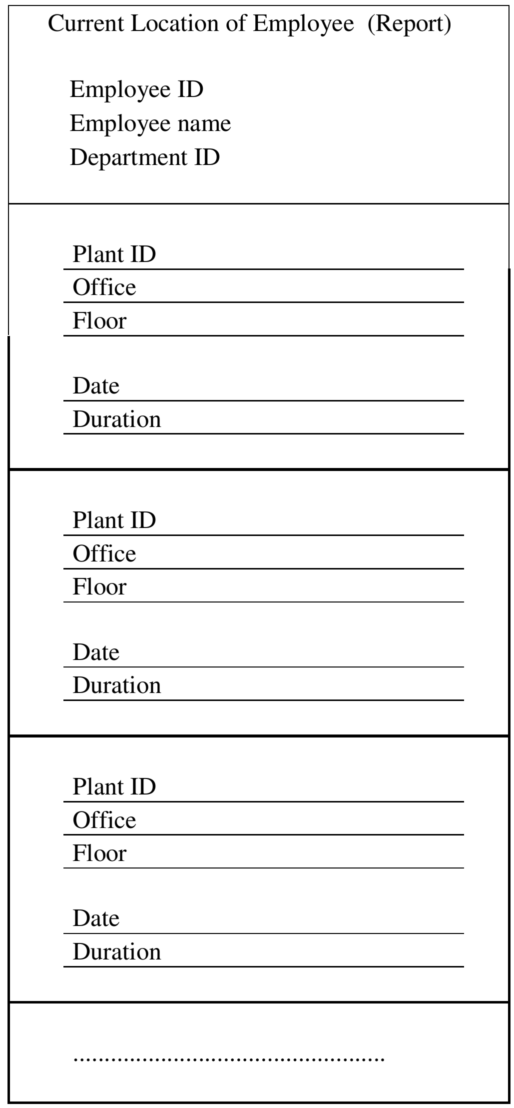

Figure 3.38. Sketch of Real Time Data Screen of Employee Tracker

3.2.5.6.2. Attendance Analysis Report Module: To analyze attendance throughout the company, from employee to the company basis, an reporting tool can be developed. According to the given criteria level, reports involve general to specific attendance analyses. That is, if the only criterion given is Company ID, report will be on company basis, vice versa.

The main screen of the reporting facility to input search criteria given below:

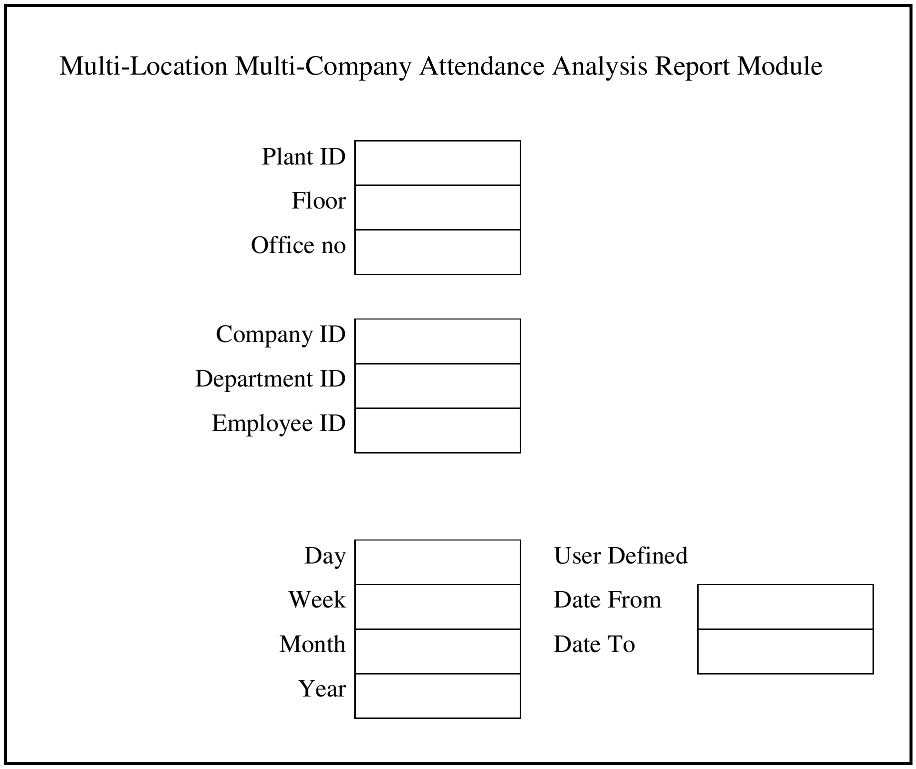

Figure 3.39. Sketch of Input Screen of Attendance Analysis Report

After executing the program with the criteria given above, the resultant report can be screened in the format below:

Attendance Analysis Report

Plant ID
Floor
Office no

Company ID
Department ID
Employee ID

Day
Week
Month
Year
User Defined
Date From
Date To

Attendance Rate
Total Absence Rate
No. Of Leave Days
No. Of Vacation Days
No. Of "No Excuse" Days

Building Usage Rate
Floor Usage Rate
Office Usage Rate

Figure 3.40. Sketch of Output Screen of Attendance Analysis Report

3.2.5.7. Data Flow Diagram: On the data flow diagram (see Figure 3.41), data flow paths are shown with arrows including the direction of the flow and arrows are given numbers. In Appendix A.2., XML data is shown with those respective flow numbers.

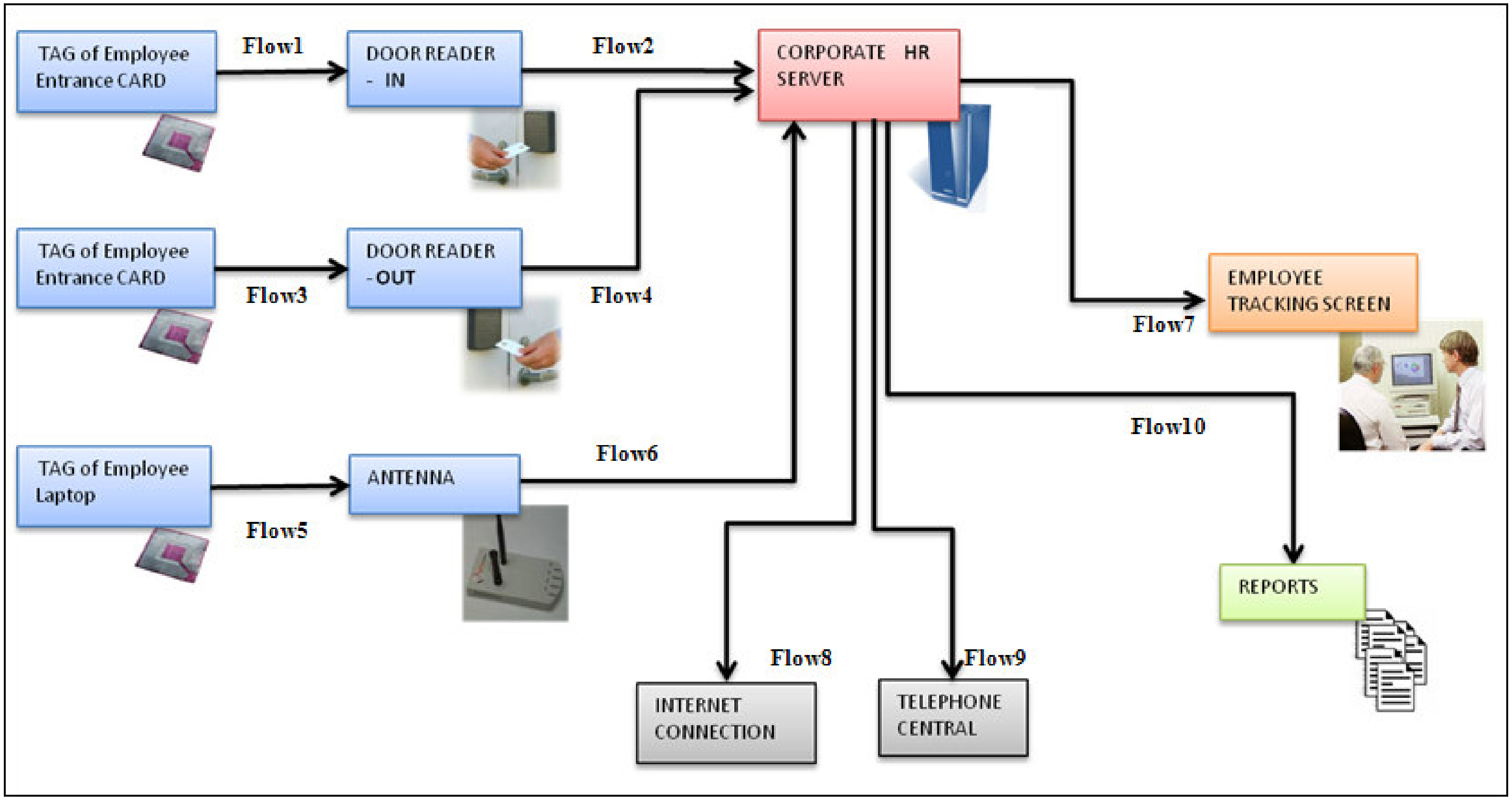

Figure 3.41. Data Flow Diagram – RFID Employee Control Model

3.2.6. Financial Assessment of the Proposed System

In this part of the study, a quantitative feasibility study, encompassing the costs and benefits of RFID technology, has been carried out to quantify the economical profitability of the Employee Control System implementation and to provide a justification for technology investments.

3.2.6.1. Costs and Benefits of RFID Deployment: The benefit and cost items for the Employee control system is listed in Table 3.31. For this study, based on the system defined and designed, benefits and costs can be grouped under 5 items (see Table 3.31):

Table 3.31. Benefit and Cost Items

Benefit and Cost Items	Remarks
Benefit item 1	Increased accessibility
Benefit item 2	Increased security
Cost item 1	Readers, antennas and other infrastructure
Cost item 2	Software and consulting of Project
Cost item 3	Tagging and maintenance

We have to note that it is hard to quantify the benefits of security, as a result it is not included in the numerical analysis.

3.2.6.2. Financial Assessment: Business case in this study involves implementation of Employee Control RFID project in a company having 100 employees. They work in 10 offices in this business case. Financial metrics [20] are quantified over a 5-year period and considering a 5% interest rate. Again, high inflation rate in our country is not considered o make the assessment simpler and again Euro is used as the currency. The cost of rent, RFID equipments, implementation project costs, shown in Table 3.16, have been derived from literature, market prices, catalogues of RFID equipment producers and vendors [19], newspapers and websites [33].

We can assume that RFID system deployed can maintain 20 minutes of time saving benefit of efficiency increase per worker, per week. In a company of 100 workers, paid € 2000 monthly, will gain € 770,37 annually per worker and € 77037per year for the whole company, say € 77000. Note that, a white collar employee of private sector has to work 45 hours a week, in our country. Cost of door and table readers are € 100 and antenna are €500 in the market. Cards having RFID chips are sold for € 1. Consulting and software cost can be assumed to be € 100000 for this simpler project, parallel to this, maintenance is € 10000 annually. Briefly, annual benefits and costs are calculated for the items (see Table 3.32 and Table 3.33).

Table 3.32. Annual Benefits of RFID Deployment

		Annual Saving per Employee	# of Employees	Annual Subtotals	Annual Totals
Benefit item 1	Increased accessibility	€ 770,37	100	€ 77000	€ 77000

Table 3.33. Annual Costs of RFID Deployment

		Annual Cost Per Item	# of Items	Annual Subtotals	Annual Totals
Cost item 1 *					
	Cost of RFID Door Readers (10 rooms x 2)	€ 100	20	€ 2.000	
	Cost of RFID antenna (1 per room)	€ 500	10	€ 5.000	
	Cost of RFID readers on tables (1 per chair)	€ 100	100	€ 10.000	
	Other hardware and Infrastructure			€ 40.000	€ 57.000
Cost item 2 *	RFID software and Consulting			€ 100.000	€ 100.000
Cost item 3	Tags (In "Employee card" form)**	€ 1	100	€ 100	
	Tags (In sticker form for Laptops) **	€ 0,15	100	€ 15	
	Maintenance			€ 10.000	€ 10.000

* Only for the first year of deployment
** Since it is a very low cost element, it is ignored in calculations

Standard financial metrics are used for assessment [20]. These are:

- Net cash flow
- Cumulative Cash flow
- Payback Period
- Return on Investment (ROI)
- Internal Rate of Return
- Net present value (NPV)

According to the mentioned numbers in Table 3.32 and Table 3.33, calculations are made. Results can be seen in Table 3.34, Figure 3.42, Figure 3.43, Table 3.35, Table 3.36 Table 3.37, and Table 3.38. Note that all numbers are given in € 1000 units.

Table 3.34. Net Cash Flow

	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
Cash Inflows / Benefits and Gains		`				
Benefit item 1	77	77	77	77	77	385
Total cash inflows	77	77	77	77	77	385
Cash Outflows / Costs & Expenses						
Cost item 1	-57					-57
Cost item 2	-100					-100
Cost item 3	-10	-10	-10	-10	-10	-50
Total cash outflows	-167	-10	-10	-10	-10	-207
Cash Flow Summary						
Total inflows	77	77	77	77	77	385
Total outflows	-167	-10	-10	-10	-10	-207
Net cash flow	-90	67	67	67	67	178

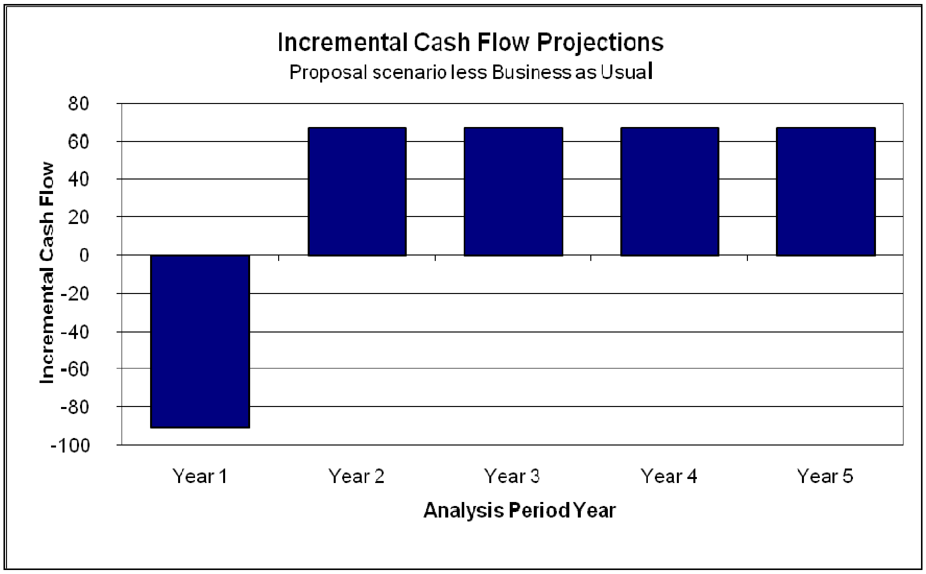

Figure 3.42. Graph of Net Cash Flow for Analysis Period

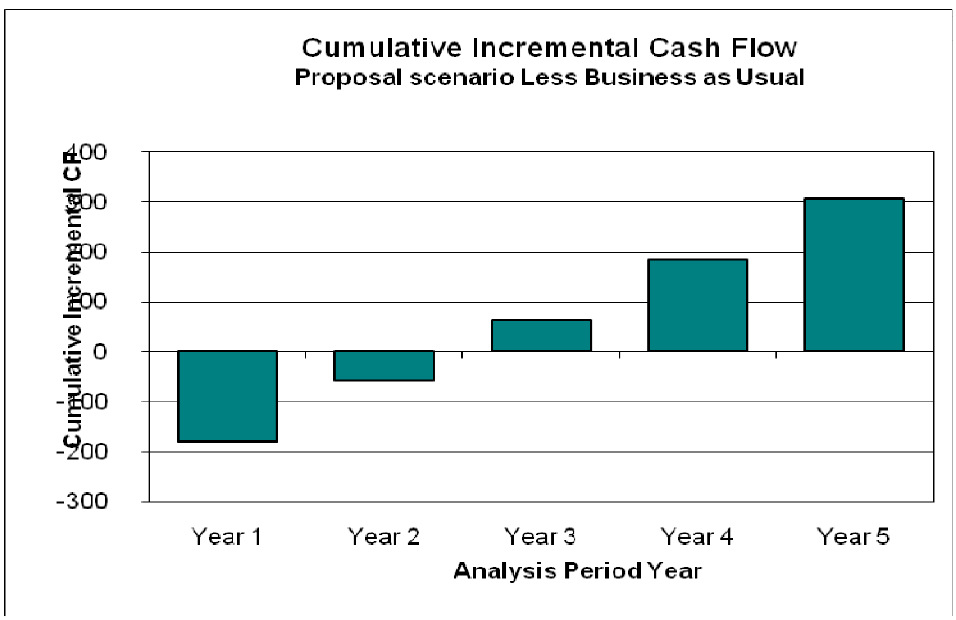

Figure 3.43. Graph of Cumulative Cash Flow for Analysis Period

Table 3.35. Payback Period

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Total incremental inflows	77	77	77	77	77	385
Total incremental outflows	-167	-10	-10	-10	-10	-207
Net incremental cash flow	-90	67	67	67	67	178
Cumulative Incremental Cash Flow	-90	-23	44	111	178	
Payback Period:	2,3	Years				

Table 3.36. Return on Investment

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Total incremental inflows	77	77	77	77	77	385
Total incremental outflows	-167	-10	-10	-10	-10	-207
23,5%	**Simple ROI, 3 years**					
56,3%	**Simple ROI, 4 years**					
86,0%	**Simple ROI, 5 years**					

Table 3.37. Internal Rate of Return

Initial guess for the IRR (0% - 100%) : 5,0%

Year 1	Year 2	Year 3	Year 4	Year 5	Total
-90	67	67	67	67	178

Internal Rate of Return (IRR) 64,2%

Table 3.38. Net Present Value

Interest rate for discounting (0 - 100%)				5,0%	
Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
-90	67	67	67	67	178
Discounting at Year End: **Discounted Cash Flow Stream**					**NPV**
-82	55	50	46	42	111
Discounting at Mid-Year **Discounted Cash Flow Stream**					**NPV**
-86	58	53	48	44	117

3.2.6.3. Analysis of the Results: The most critical financial measure, Payback Period, shows that RFID deployment will pay-off itself after 2,3 years.

Investors will have a profit after 2 years, according to the net and cumulative cash flows. Additionally, positive Return on Investment is achieved. But, for the first year of deployment, the company will face high investment cost of (€ 167.000) and net cash outflow (€ 90.000). Starting with the second year, the benefit of time saving will pay off the costs and at the beginning of the third year, benefits will totally pay off the all cost. Internal rate of return (64,2%) is again seriously high compared to 5% IRR.

According to the financial metric, in the long run, the company will gain high benefits by deploying RFID, but the financial metrics in this study are based on assumptions at some points. More precise numbers will help the actual investors to make the metrics healthier. But, the whole analysis in the study, except the actual numbers for some cost/benefit items, will form the basis for financial assessment and decision making.

Finally, it can be concluded that RFID deployment with proposed model in this business case, is feasible. Different business cases can give different results, but the approach should be the same with the one in this study. We have to note that, this financial analysis is sensitive to number of employees and their salaries. A company with a high number of employees with relatively high salaries can benefit from the RFID deployment.

4. CONCLUSION AND FUTURE WORK

Throughout this thesis, current RFID applications are examined and two functional control system designs are proposed.

Functional, technological and financial feasibility of designed "RFID Based Payment Control System for Stores" and "RFID Based Employee Control System for Multi-Plant/Multi-Location Companies" are examined. Functionalities of both systems are satisfactory and advantageous for the implementing institutions and their users. From the technology view, current technology allows real life implementation of both of the systems. Financially, payback periods are approximately 2,5 years for both systems, for relatively large businesses. That is, in the medium term, proposed systems are feasible. As a result, through its conceptual design and functional specification we see that the proposed designs can be verified for real life applications, today.

Specifically RFID based payment system in stores is burgeoning in developed countries like USA, Germany and Japan. As the RFID technology develops, concurrent reading performance of RFID tags is getting improved and cost of RFID tags are decreasing month by month. These will be resulting in replacement of classical barcodes in the stores with the RFID tags, followed by new payment methods proposed.

Employee tracking system for non-territorial offices can fulfill the need of the company efficiently. Specifically for employee tracking, privacy issues in the community must be cleared. Even tagged products are still seen as a violation to the privacy in countries using RFID technology intensely. Employee level tracking with RFID tags may not be controversial in short run, if the benefits can be explained to the companies and employees. In fact, everyone with a cellular phone can be traced on real-time basis, today.

Having potential for the future, I believe these control system designs will be common real life applications soon. But, first social and case-based detailed financial feasibility must be verified for community wide applications, for both of the proposed systems.

APPENDIX A: XML CODES FOR DATA FLOW DIAGRAMS

A.1. XML Codes for RFID Based Payment Control System

Below the transported data in XML structure through the components of the Proposed RFID Self Check-Out system can be seen. The Flow numbers correspond to the numbers given in Figure 3.5.

Flow1

<Tag_data>
<Product_ID> 123456789 </Product_ID>
</Tag_data>

Flow2

<Product_Reader_data>
<Product_ID> 123456789 </Product_ID>
<RF_Cashier_ID> Cashier005 </RF_Cashier_ID>
<Cashier_Read_Date> 05082007 </Cashier_Read_Date>
<Cashier_Read_Time> 152215</Cashier_Read_Time>
</Product_Reader_data>

Flow3

<Credit_Card_data>
<Credit_Card_ID> 231681335143518363154343546564</Credit_Card_ID>
<Credit_Card_Number> 4820250125960032 </Credit_Card_Number>
<Credit_Card_Type> MasterCard </Credit_Card_Type>
</Credit_Card_data>

Flow4

<Credit_Card_Reader_data>
<Credit_Card_Reader_ID> CCread0006</Credit_Card_Reader_ID>
<Credit_Card_ID> 231681335143518363154343546564</Credit_Card_ID>
<Credit_Card_Number> 4820250125960032 </Credit_Card_Number>
<Credit_Card_Type> MasterCard </Credit_Card_Type>

<CC_Read_Date> 05082007 </CC_Read_Date>
<CC_Read_Time> 152332</CC_Read_Time>
</Credit_Card_Reader_data>

Flow5

<Transaction_Sent_data>
<Transaction_ID> TRS992254100145</Transaction_ID >
<Total_Sum> 17,91</Total_Sum>
<Credit_Card_ID> 231681335143518363154343546564</Credit_Card_ID>
<Credit_Card_Number> 4820250125960032 </Credit_Card_Number>
<Credit_Card_Type> MasterCard </Credit_Card_Type>
<Transaction_Sent_Date> 05082007 </Transaction_Sent_Date>
<Transaction_Sent_Time> 152405</Transaction_Sent_Time>
</Transaction_Sent_data>

Flow6

<Bank_Transaction_SentBack_data>
<Transaction_ID> TRS992254100145</Transaction_ID >
<Total_Sum> 17,91</Total_Sum>
<Bank_Transaction_SentBack_Date> 05082007 </Bank_Transaction_SentBack_Date>
<Bank_Transaction_SentBack_Time> 152439</Bank_Transaction_SentBack_Time>
<BankMessage_ID>BNK0001</BankMessage_ID>
<BankMessage_Text>"Transaction Successful" </BankMessage_Text>
</Bank_Transaction_SentBack_data>

Flow7

<Invoice_data>
<Invoice_ID>0000056</Invoice_ID>
<Invoice_Issue_Date>05082007 </Invoice_Issue_Date>
<Invoice_Issue_Time>152455</Invoice_Issue_Time>
<RF_Cashier_ID> Cashier005 </RF_Cashier_ID>

<Line_1>

<Product_Definition>Detergent 3 Kg </Product_Definition>
<Item_Amount>1</Item_Amount>
<Unit_Price>12,25</Unit_Price>
<Campaign_Name>Supermarket discount Festival - Special Price</Campaign_Name>
<Discount_Total>1,20</Discount_Total>
<SubTotal>11,05</SubTotal>
<Incurred_VAT>18%</Incurred_VAT>
<Incurred_VAT_Amount>1,99</Incurred_VAT_Amount>
</Line_1>
<Line_2>
<Product_Definition> Yoghurt 500 gr</Product_Definition>
<Item_Amount>2</Item_Amount>
<Unit_Price>2,58</Unit_Price>
<Campaign_Name>Brand Special Discount - Seasonal</Campaign_Name>
<Discount_Total>0,15</Discount_Total>
<SubTotal>4,86</SubTotal>
<Incurred_VAT>18%</Incurred_VAT>
<Incurred_VAT_Amount>0,87</Incurred_VAT_Amount>
</Line_2>
<Line_3>
<Product_Definition> 20 pack cheving gum</Product_Definition>
<Item_Amount>4</Item_Amount>
<Unit_Price>0,50</Unit_Price>
<Campaign_Name></Campaign_Name>
<Discount_Total></Discount_Total>
<SubTotal>2,00</SubTotal>
<Incurred_VAT>18%</Incurred_VAT>
<Incurred_VAT_Amount>0,36</Incurred_VAT_Amount>
</Line_3>

<Total_Sum> 17,91</Total_Sum>

THANK YOU!

</Invoice_data>

Flow8

<Cashier_Screen_data>

<Line_1>

<Product_Definition>Detergent 3 Kg </Product_Definition>

<Item_Amount>1</Item_Amount>

<Unit_Price>12,25</Unit_Price>

<Campaign_Name>Supermarket discount Festival - Special Price</Campaign_Name>

<Discount_Total>1,20</Discount_Total>

<SubTotal>11,05</SubTotal>

</Line_1>

<Line_2>

<Product_Definition> Yoghurt 500 gr</Product_Definition>

<Item_Amount>2</Item_Amount>

<Unit_Price>2,58</Unit_Price>

<Campaign_Name>Brand Special Discount - Seasonal</Campaign_Name>

<Discount_Total>0,15</Discount_Total>

<SubTotal>4,86</SubTotal>

</Line_2>

<Line_3>

<Product_Definition> 20 pack cheving gum</Product_Definition>

<Item_Amount>4</Item_Amount>

<Unit_Price>0,50</Unit_Price>

<Campaign_Name></Campaign_Name>

<Discount_Total></Discount_Total>

<SubTotal>2,00</SubTotal>

</Line_3>

<Total_Sum> 17,91</Total_Sum>

DEAR

<Customer_Name>Susie Rottmann</Customer_Name>

<SM_message_ID>SM0001</SM_message_ID>

<SM_message_Text>"Your Transaction is Successful"</SM_message_Text>

THANK YOU!

</Cashier_Screen_data>

Flow9

<Lock_Door_data>

<SM_message_ID>SM0001</SM_message_ID>

</Lock_Door_data>

A.2. XML Codes for RFID Based Employee Control System

Below the transported data in XML structure through the components of the proposed RFID Employee Control System can be seen. The Flow numbers correspond to the numbers given in Figure 3.41.

Flow1

<Tag_data>
<Employee_ID> 1002569999901</Employee_ID>
</Tag_data>

Flow2

<Door_data>
<Door_Reader_ID> Door990058</Door_Reader_ID>
<Door_Character> IN</Door_Character>
<Door_Read_Date> 18062007</Door_Read_Date>
<Door_Read_Time> 115208</Door_Read_Time>
<Employee_ID> 1002569999901</Employee_ID>
</Door_data>

Flow3

<Tag_data>
<Employee_ID> 1002569999901</Employee_ID>
</Tag_data>

Flow4

<Door_data>
<Door_Reader_ID> Door990022</Door_Reader_ID>
<Door_Character> OUT</Door_Character>
<Door_Read_Date> 18062007</Door_Read_Date>
<Door_Read_Time> 182507</Door_Read_Time>
<Employee_ID> 1002569999901</Employee_ID>
</Door_data>

Flow5

<Tag_data>

<Employee_ID> 1002569999901</Employee_ID>

</Tag_data>

Flow6

<Table_data>

<Table_Reader_ID> Tab001855</Table_Reader_ID>

<Occupied_Indicator> YES</Occupied_Indicator>

<Employee_ID> 1002569999901</Employee_ID>

</Table_data>

Flow7

<Screen_data>

<Employee_ID> 1002569999901</Employee_ID>

<Employee_Name> James Watson</Employee_Name>

<Part_Full_T> FULL</Part_Full_T>

<Company_ID> PCMN</Company_ID>

<Company_Name> Pacman Computers</Company_Name>

<Department_ID> FI</Department_ID>

<Department_Name> Finance</Department_Name>

<Employee_Status> IN-TABLE</Employee_Status>

<Duration> 1h35min</Duration>

<Employee_Last_Action_Date> 18062007</Employee_Last_Action_Date>

<Employee_Last_Action_Time>115208</Employee_Last_Action_Time>

<Plant_ID> 0030</Plant_ID>

<Plant_Name> Chicago Headquarters</Plant_Name>

<Floor> 7</Floor>

<Office_Number> 708</Office_Number>

<Table_Number>012</Table_Number>

<Telephone_Number> 4270</Telephone_Number>

</Screen_data>

Flow8 (Signal)

If Occupied_Indicator= YES,

Send Signal to activate Telephone and its Screen

Flow9 (Signal)

If Occupied_Indicator= YES,

Send Signal to activate Internet Connection

Flow10

This data flow includes all data passed through the server. All "Employee Tracking" data is accumulated and consolidated to produce reports.

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