IMPROVING REVERSE SUPPLY CHAIN MANAGEMENT WITH INFORMATION AND COMMUNICATION TECHNOLOGIES

A THESIS SUBMITTED TO

THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCE

OF ATILIM UNIVERSITY

BY SERCAN NOYAN GERMİYANOĞLU

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE

OF MASTER OF SCIENCE

IN INFORMATION TECHNOLOGY

DECEMBER 2015

Approval of the Graduate School of Natural and Applied Sciences, Atılım University.

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I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

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ABSTRACT

IMPROVING REVERSE SUPPLY CHAIN MANAGEMENT WITH INFORMATION AND COMMUNICATION TECHNOLOGIES

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M.S., Information Technology

Supervisor: Assoc. Prof. Dr. Murat KOYUNCU

December 2015, 67 pages

With the advances in technology, Supply Chain Management (SCM) systems have become much more popular in the industry to increase performance of involved parties. Information and Communication Technologies (ICT) contribute significantly to the development of an effective SCM system. In general, supply chain includes flow of materials/goods/services from suppliers towards consumers, which is called Forward Supply Chain Management (FSCM). However, Reverse Supply Chain Management (RSCM), which handles reverse flow of goods, is becoming more and more popular in recent years. Customers have started to prefer companies having the capability of RSCM. In the future, it will definitely become indispensable part of a SCM system.

In this thesis, a SCM system having RSCM capabilities is modeled giving special focus on the usage of ICT. Three different RSCM processes (Customer Return, Out-of-product Return and Repair and Non-Repair Situation Return) are modeled separately using sequence diagram of UML and ICT usage is analyzed in each one to improve the process. These modeled processes are compared with the RSCM model of a company to determine its applicability in real life. The aim of the study is to show how the RSCM processes can be improved by efficient usage of ICT. Companies that can achieve this can gain competitive advantages over their competitors. This study is important to alleviate the lack of studies in this field and may help to companies having intension to improve their RSCM.

Keywords: *Supply Chain Management (SCM), Reverse Supply Chain Management (RSCM), Information and Communication Technologies (ICT)*

ÖZ

BİLGİ VE İLETİŞİM TEKNOLOJİLERİ İLE TERS TEDARİK ZİNCİRİ YÖNETİMİ GELİŞTİRİLMESİ

GERMİYANOĞLU, Sercan Noyan

Yüksek Lisans, Bilgi Teknolojileri

Tez Yöneticisi: Doç. Dr. Murat KOYUNCU

Aralık 2015, 67 sayfa

Teknolojideki gelişmelerle birlikte, Tedarik Zinciri Yönetim (TZY) sistemleri, içerilen tarafların performansını arttırmak için sektörde daha çok popüler hale gelmiştir. Bilgi ve İletişim Teknolojileri (BİT) etkin bir TZY sisteminin gelişmesine önemli katkı sağlamaktadır. Genel olarak, tedarik zinciri İleri Tedarik Zinciri Yönetimi (İTZY) denilen tedarikçilerden tüketicilere doğru malzeme/mal/hizmet akışını içerir. Ancak, malların ters akışını idare eden Ters Tedarik Zinciri Yönetimi (TTZY) son yıllarda daha fazla popüler hale gelmektedir. Müşteriler TTZY kabiliyetine sahip şirketleri tercih etmeye başlamışlardır. Gelecekte, bu kesinlikle TZY sistemlerinin vazgeçilmez bir parçası haline gelecektir.

Bu tezde, TTZY kabiliyetine sahip olan bir TZY sistemi BİT kullanımına özel odak verilerek modellenmiştir. 3 farklı TTZY süreçleri (müşteri iadesi, kullanımı bitmiş ürün iadesi ve onarım ve onarılamama durum iadesi) BMD(Birleşik Modelleme Dili)'nin sıra diyagramı kullanılarak ayrı ayrı modellenmiştir ve BİT kullanımı süreci geliştirmek için her birinde analiz edilmiştir. Bu modellenen süreçler, gerçek hayatta uygulanabilirliğini tespit etmek amacıyla bir şirketin TTZY modeli ile kıyaslanmıştır. Bu çalışmanın amacı TTZY süreçlerinin BİT'in etkin kullanımı ile iyileştirilebileceğini göstermektir. Bunu başarabilen şirketler rakipleri karşısında rekabet avantajları elde edebilir. Bu çalışma, bu alandaki boşluğu doldurmak açısından önemlidir ve kendi TTZY geliştirmek niyetinde olan şirketlere yardımcı olabilir.

Anahtar Kelimeler: *Tedarik Zinciri Yönetimi (TZY), Ters Tedarik Zinciri Yönetimi (TTZY), Bilgi ve İletişim Teknolojileri (BİT)*

To My Parents

ACKNOWLEDGEMENTS

First of all, I would like to take an opportunity to say my profound gratitude to Assoc. Prof. Dr. Murat KOYUNCU for his friendly approach, wonderful assistance and great support during my thesis.

I would like to give my special thanks to Asst. Prof. Kadir Önem, Academic Personal in Urology department of Ondokuz Mayıs University to support me to finish my thesis.

I am particularly grateful my friends for their understanding and support during my thesis.

At last, I am profoundly grateful to my parents. They have always supported me and believe in me during my whole life as well as during my thesis. I also thank to them for their valuable help to finish my thesis.

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LIST OF ABBREVIATIONS

2D Printing	-	2 Dimensional Printing
3D Printing	-	3 Dimensional Printing
3PLS	-	Third-party logistic services
CRM	-	Customer Relation Management
EDI	-	Electronic Data Interchange
EOL	-	End of Life
ERP	-	Enterprise Resource Planning
FIPS-140	-	Federal Information Processing Standard
FSCM	-	Forward Supply Chain Management
GPS	-	Global Positioning System
ICT	-	Information and Communication Technologies
IT	-	Information Technology
ITS	-	Intelligent Transport System
LEAP	-	Learning Automata-Based Polling (wireless protocol)
RADIUS	-	Remote Authentication Dial-In User Service
RFID	-	Radio Frequency Identification System
RSCM	-	Reverse Supply Chain Management
SC	-	Supply Chain
SCM	-	Supply Chain Management
UML	-	Unified Modeling Language
VPN	-	Virtual Private Network
WPA	-	Wi-Fi Protected Access
WPA2	-	Wi-Fi Protected Access II

CHAPTER 1

INTRODUCTION

With the advances in technology, Supply Chain Management (SCM) has become much more effective in the industry in terms of producing the products **[1]**. That's why companies have changed the way of producing the products with the help of information systems **[2]**. Information systems used in Supply Chain (SC) provide management of it effectively in a technological environment **[3]**. Therefore, these systems lead to produce, stock, packet and deliver products easily to their customers from companies and get raw materials from suppliers in a short time **[4]**. Today, companies in SC highly depend on the usage of information systems for their needs and the usage of these systems have a big importance for these companies.

Nowadays, SCM should be considered from two perspectives. First one starts with suppliers for getting raw materials and ends up with selling products, commodities and goods produced from these materials to customers. This is called as Forward Supply Chain Management (FSCM). The second one is that sold products are got back because of a reason and this is called as Reverse Supply Chain Management (RSCM). **[10]**

Because SCM is generally described and thought as forward, mostly studies focus on the information system usages in FSCM processes **[5]**. In the literature, existing studies generally investigate forward SCM and ignore reverse SCM. Companies invest on FSCM systems ignoring again reverse processes. However, there can be a big issue for these companies when they come across with reverse processes of SCM **[6]**. There are only a few studies investigating reverse supply chain management process **[7]** in the literature. It means that people generally consider RSCM as the verge of the desk and ignore it. When we consider economic side of SCM, RSCM is a critical requirement for many corporations and companies to sustain and maintain their supply chain work flow in an effective and efficient way **[8]**. Thus, they can create a big opportunity in the market area with the help of well-defined RSCM and gain big advantage in the market area compared to others **[8]**. They can increase satisfaction level of existing customers and attract new customers in the market.

Another important point is that RSCM is generally thought as marketing and material engineering in the most cases and usage of information systems in RSCM is an open area to be investigated.

Johnson, Leenders and Flynn **[9]** focus on the FSCM with the usage of information system integrated in SCM's processes. However, they do not give its usage in detail. Moreover, RSCM is evaluated as material and marketing engineering without considering information technologies. Although there are many technologies used in SCM, they only focus on the usage of EDI and RFID in FSCM, and ignore other technologies and RSCM.

Chopra and Meindl**[10]** give general information about SCM with its processes and information technologies used in these processes. However, the focus is on the FSCM. RSCM and IT usage for it is again ignored.

Wang **[11]** focuses on the information systems usage in SCM. He especially emphasizes IT usage to analyze, assess and evaluate the performance of departments. RSCM is also ignored in that study.

Haibo**[12]** designs a UML use case to explain the usage of information systems. Although he mention about RSCM in his use case diagrams, he does not explain the usage of information systems in RSCM.

Mingdi, Minghai and Xin **[13]** investigate FSCM and RSCM for auto sector. They propose some flow models in both directions. However, they consider FSCM and RSCM as marketing and material engineering and they do not consider information technology usage.

Ferguson and Hadar**[14]** investigate the usage of cloud computing in SCM and optimization of SCM and controlled software, hardware and management through cloud computing. However, they ignore RSCM.

In this thesis, the usage of Information and Communication Technologies (ICT) in a RSCM model is investigated. In the scope of the study, a SCM system having RSCM capabilities is modeled emphasizing ICT usage. Three different RSCM requirements/cases of its processes are modeled separately and information technology usage is analyzed in each one to improve the model. The three RSCM requirements are as follows.

* Product returns in case of customer dissatisfaction

* Product renewal/return for an out-of-date product

* Repair Product when product is repairable and demand new product when product is not repairable

The work flows for the given processes are modeled using sequence diagram of UML. In this way, processes are depicted in a visual and standard way to increase understandability of the model. Then, the flows are explained in detail emphasizing the ICT usage in the processes.

The contribution of this thesis is to highlight the usage of ICT in RSCM because existing studies directly focus on FSCM and completely ignore RSCM or investigate it in a limited way. Every year, RSCM becomes more and more important than the past. On the other hand, ICT usage increases in SCM as well as other fields. The RSCM processes can be improved by efficient usage of information technologies. Companies that can achieve this can gain competitive advantages over their competitors. This study is important to alleviate the lack of studies in this field and may help to companies having intension to improve their RSCM.

In this thesis, only 3 RSCM processes, which are initiated either by customers or firms, are considered. However, there may be many other RSCM processes which can be initiated by different entities such as warehouse, collection areas, retrieving warehouse, distribution center, and stores and so on.

The thesis is organized as follows: Some basic information about SCM, its processes, RSCM and its processes are given in Chapter 2. In Chapter 3, the usage of information and communication technologies in SCM is mentioned. In Chapter 4, several RSCM processes and ICT usage in them are shown with sequence diagrams. In Chapter 5, the modeled processes are compared with the RSCM model of a company to determine its applicability in real life. Chapter 6 concludes the thesis.

CHAPTER 2

BACKGROUND

2.1 What is Supply Chain Management SCM)?

SCM is the process that starts with providing the source of raw materials, then bringing them to the manufacturing area and if it is necessary storing them and getting them into the production area to get the product, commercializing them in the market and finally supplying product to the end users or customers **[11]**. This management provides all the flow information starting with raw materials and ending with the products delivered to end-users or customers. It helps for a successful competition in the global marketplace **[12]**. By the development of technology day by day, competition reaches up the highest level for possessing different kinds of products and developing new ones **[12]**. Therefore, customers are now more selective to purchase new products than the past and a company with an effective SCM can affect customer preferences.

In order to explain SCM better, its processes are illustrated in Figure 2.1 **[13] [14] [15][16][17].** In the figure, the SCM processes inside a country are presented. It starts with gathering raw materials from suppliers, then sending them to the manufacturing area for producing the products and putting them in the stock in the warehouse, and then these products are sent to the distribution area. Next these products are put into stock in the distribution center and SC firms determine products to be delivered to the city or rural areas with respect to their transportation lines. When the determination process is completed, some of these products are sent to the retailer stores by passing across city hub, others are sent to the shops located in village or a tiny city by passing across regional consolidation center. After these products are put in the shelves of the retailer stores and shops, the customer can purchase them.

Moreover, during the process of SCM, firms must be responsible for controlling each entity's process and abiding the status of each ones because both processes and entities are under the control of the government rules and regulations determined whether it is legal or illicit in SCM. At the same time, banks and firms are also controlled by the government rules

and regulations in SCM processes. The reason why these regulations are required for SCM is to prevent the tax evasion and provide well-defined structure of SCM in the legal platform **[18]**.

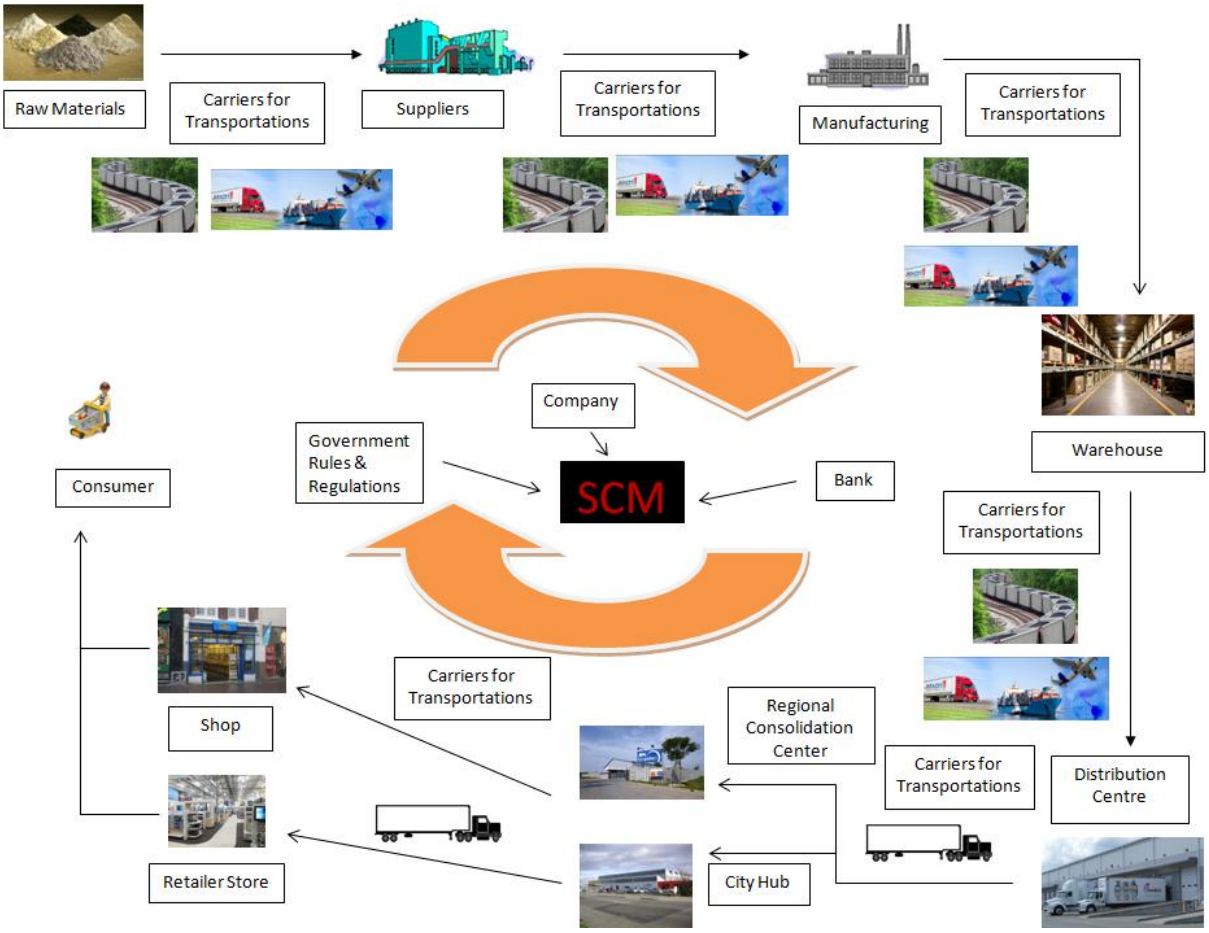


Figure 2.1: SCM Processes

2.2 Main Processes of SCM

A typical SCM includes in deployment and transportation, manufacturing, supplying and purchasing, stock management, warehousing, packaging, material handling, after-sale services, maintenance and repair as shown in Figure 2.2. Each process is explained below step by step in detail.

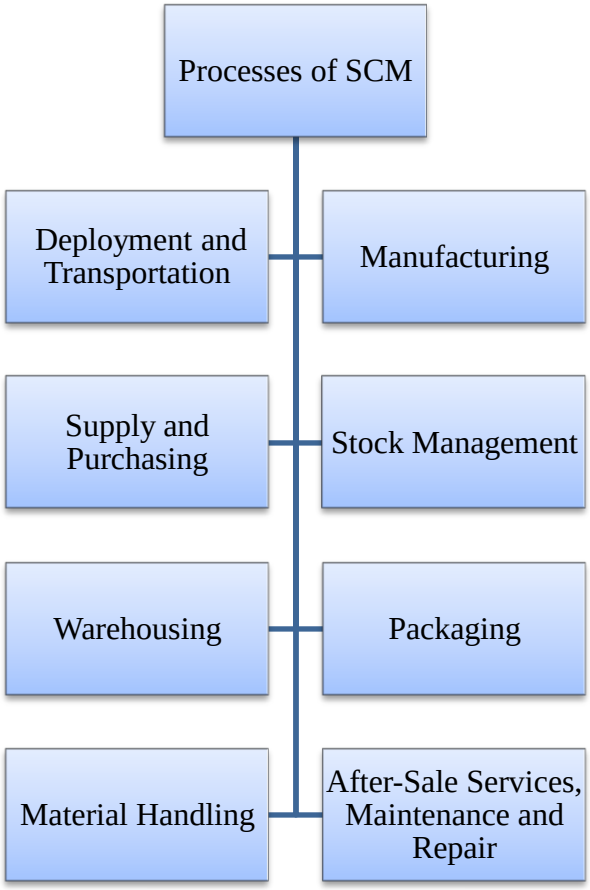


Figure 2.2: Processes of SCM **[11]**

2.2.1 Deployment and Transportation

It is the process to deploy and transport the supply chain firms' products to their customers securely. In this phase, firms consider to have an adequate location to transport and deploy their products to customers easily, decrease the length of transportation and deployment time for delivery, create a good impression on their customers by delivering products at the right time, offering appreciate qualifying delivery cost to customers **[19]**.

2.2.2 Manufacturing

Manufacturing is the process of converting from raw materials to products and includes in manufacturing activities in the supply chain management to produce the products**[6]**. Before manufacturing the product, manufacturing firms should determine the location of manufacturing foundation with supplying equipments and devices used by

manufacturing, posses the information about how to manufacture the product and marketing information for providing raw materials, equipments and devices with appropriate cost **[20]**.

Manufacturing firms provide necessary information about manufacturing and then create their own plan with respect to their information. Firstly, they directly focus on the planning of manufacturing, capacity, operations and material supplements. In the planning of manufacturing, these firms determine the location of manufacturing and stock area, number of products to be manufactured in a certain time, products to be stored in the stock after manufacturing. In the planning of capacity, these firms manufacture their products with respect to the capacity of manufacturing and determine whether the capacity of stock is appropriate or not after and before products are sent to the stock. In the planning of operations, these firms determine which operations are used to manufacture their product. In the planning of material supplements, these firms determine the materials to be used to manufacture their product**[21]**.

2.2.3 Supplying and Purchasing

Purchasing is the process that the customers buy their products, services and transportation from manufacturers to get to their needs whereas supplying is the process that the supply chain firms supply their essential assets and services to perform their logistic activities **[22]**.

In this process, the supply chain firms determine their essential assets and services for supply process, make negotiations with suppliers to get raw materials and evaluate to establish good relationships with suppliers whereas companies determine their essential assets and services to their customers to get their products for purchasing process and provide their customers' product to them at the right time in the right place **[23]**.

2.2.4 Stock Management

Before the products are delivered to customers, they are waited for a certain time in the stock and companies control the stock levels and then deliver them to the customers after control process is completed. This is called as stock management. Furthermore, it keeps the essential records about these products with respect to input and output.

For the stock, firms determine which time their customers' demands occur, which products are ready in the stock for transportation and what are the amounts of these products in the stock. Therefore, companies plan their own appropriate stocks to operate all activities in the stock management and determine the essential devices, equipment and staff to be used in this process. In the planning, companies possess different kinds of product with respect to customers' demands and determine appropriate transportations for delivering them to their customers. Furthermore, companies create an application to control these amounts of products in the stock. Companies also have a good and long-term relationship among stock managers and manufacturing managers for providing different kinds of products from the stock. When they control their customers' orders, they have to make a good plan for processing all orders and determine the appropriate stock level to make a good reaction for customer demands**[24]**.

2.2.5 Warehousing

It generally keeps and protects the materials and products during the period of non-use time in the stock and provides an allocation and integration of the products in the stock before delivery. It also provides the flows of products' transportation with their regulations to the customers after the products are taken off the stock **[25].**

Supply chain managers related with warehousing create their own plan for the location of the warehouses, the size and number of warehouses. The location of the warehouses is important for supply chain management because the location of those should be near the market for reaching the customers as well as bringing closer to the manufacturing for demanding the products**[37]**. The size and number of the warehouses are chosen by these managers for possessing different kinds of products with their amounts and qualities in the warehouses which are near to market areas. As a result, these managers provide a good competitive advantage in market for short time delivery processes and determine appropriate prices of products, so they attract different kinds of customer buying these products in market areas **[26].**

2.2.6 Packaging

Packaging is that the related equipment and staff package the product waiting in the warehouse. The objective of packaging for the product is to provide the transportation and identification of the products more easily. Warehouse staff uses pocketing system to monitor

how to package their product. The system helps supply chain to provide the harmony of the products with transportation, the relevant information about the product and the security of the product. Furthermore, packets should have recycling features because warehouse staff reuses them for pocketing other products in order to save money **[27].**

2.2.7 Material Handling

Material handling is the transfer movements between supplying the materials from supply points and transporting or shipping them to the destinations. Its processes are the loading and discharging of the materials and products in the vehicles, the movements of materials and products in the warehouse as well as providing the allocation, combination and security of the materials and products.

Material handling system includes in 5 sub-systems which are manual system, mechanic system, automated system, combined system and special system. Manual system means that staff and different kinds of non-engine tools are combined with each other to handle the materials. This combination provides stocking materials securely in the stock with stocking equipment, putting these materials on the shelves in the warehouses with locating equipment, transporting from one location to another in the warehouses with transportation equipments, and loading and discharging the materials in the vehicles with loading and discharging equipment. Mechanic system represents the combination of staff and supply chain equipment to transport the materials, load and discharge the materials, move the materials in the warehouse and stock. Automated system consists of a computer-based system to control material handling. Combined system means the combination of manual, mechanic and automated systems. Special system consists of devices such as hoists, ships, airplane and train used by firms to put heavy materials on the shelves and transport them from one location to another**[28].**

2.2.8 After-Sales Services, Maintenance and Repair

After sales are completed, the customers wait whether the services to after-sales, maintenance and repair are available or not from supply chain firms if they have a problem related to the products. After-sales services comprise product delivery, product mounting, and elimination of products' defects and sustaining operations of the products. If a customer has purchased a product before and he wants to renew his product, the supply chain firms give him discounts by using this service. Product mounting is that when the customers purchase

the products and demand some extra materials for the products after purchasing, the supply chain firms give this service for customers. The elimination of products' defects is that when a problem occurs, the supply chain firm provides this service for eliminating products' defects to the customers. The sustaining operations of the products is that when the products have got lack of operation in time, the supply chain firm provides this service for fixing the products' operations.**[29]**

In order to operate product properly, supply chain firms provide maintenance and repair services for their customers after purchasing. Their products constantly lose more and more their functions in time. Therefore, the customers demand the maintenance and repair services from supply chain firms to maintain the operations of their products and repair their products if these products have operational issues. Thus, these firms provide the maintenance and repair services to their customers for sustaining the competitive advantage against other firms in the supply chain and providing the reputations in the market area and keeping on their customers after purchasing. **[30]**

2.3 What is Reverse Supply Chain Management (RSCM)?

RSCM includes all activities related with the retrieval of products which is returned by customers and corporations for any reason. These reasons generally include in out-of-date, repair or non- repair situation, lose of the functionality, customer return, store and waste returns, and end of warranty or lease, which are the processes of RSCM **[10].** This can be called reverse way of FSCM. The purpose of RSCM is remanufacturing and reprocessing retrieved products by recycling. Because of this, less material is used in the production. Since RSCM causes less energy consumption and less pollution for reprocessing products, it might be called 'green logistic'. RSCM processes are shown in the Figure 2.3. Each process is explained below step by step in detail.

2.3.1 Out of Date Product Return

As the technology is developing day by day, the customers would like to buy new products because of their instincts of purchasing. However, many products are getting older and become out-of-date in short time**[35]**. Then, the customers apply for returning them to SC firms and they would like to demand a similar product having more advanced technology and more features. Then, these firms inform their transportation departments to send their vehicles for collecting these products from their customers. When collecting phase is completed, SC

firms determine whether these products can be used for producing new products or not. Thanks to this, some new products are made of the out-of date products without getting raw material. It means that such firms can save money for establishing new departments and may also allocate this money for their personal salaries. **[10]**

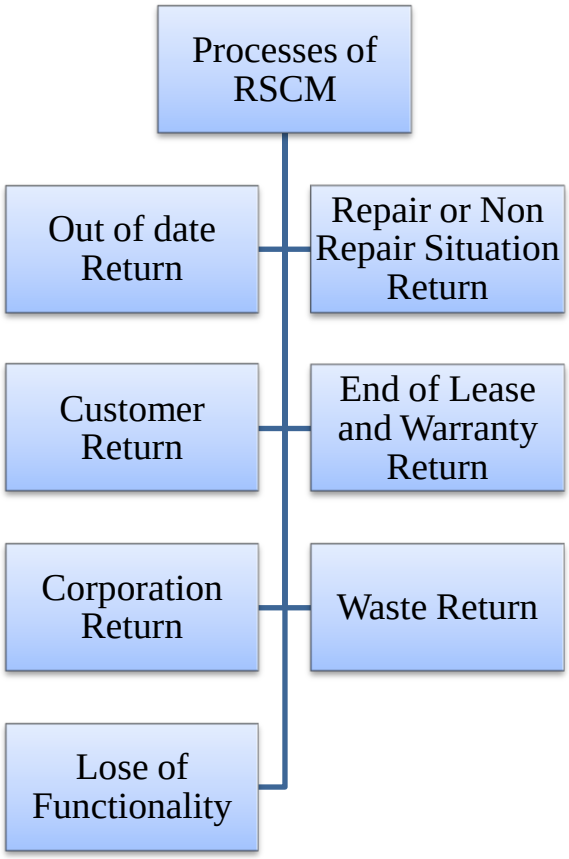


Figure 2.3: Processes of RSCM **[10]**

2.3.2 Repair or Non-Repair Situation Return

When some products lose their performance in time, these products are collected by firms' vehicles for sending them to repair area for obtaining the capability of the products again**[36]**. The reason is to repair the products rather than producing new products. In this way, SC firm does not allocate some money to produce new products when repair of the products is possible. When the repair process of products is completed, they are delivered to their customers. If repair process is not possible, these products are sent to the waste area and they are described as waste products **[31].**

According to Du and Evans **[10]**, the RSCM firms should consider their returning process of SCM for repair return. They should devise well-defined third-party logistic services (3PLS) for collecting the returned products from their customers, transporting the returned products to repair area for the process of repair and back to their collection area where these products are firstly collected, and then delivering them to their customers. While the flows of product are progressed, if 3PLS detect the defective parts of the product, they sent them to the repair area for repairing. After the repairing process is completed, these products are dispatched to the 3PLS and then 3PLS deliver them to the collection area or customers.

2.3.3 Products' Functionality Lose Return

When some products lose their functionality in time because of their usage, customers inform the SC firms to return these products because they do not want to use these non-functional products. Since firms do not want to lose their competitive advantages in the market area, The SC firms are responsible for reforming these non-functionalities in a short time. In addition, by correcting the functionalities of these products, such firms don't need to replace the existing product with a new one and they save money for other requirements **[31].**

2.3.4 Customer Return

Sometimes, customers want to return back their purchased products because of their personal reasons like product dissatisfaction, better facilities in other stores such as free price of the second product and reasonable price of the second product, and country's political issues such as war and embargo. Therefore, SC firms should devise their well-defined disposition strategy in order not to come across any problems in the returning process. This strategy depends on the condition of the product for reselling. If customers return back their purchased product without opening the package, the product can be resold as a new one. If the product package is opened, the SC firms check whether the product needs testing and refurbishing. Another option is selling the returned product in the outlet where the customers can buy refurbishing products for resale. If the returned product is severely damaged because of customer's misuse and improper handling, the returned product is called as End-Of-Life (EOL) product and it must be sent to the relevant places for processing and re-processing operations to produce new product **[10].**

2.3.5 Corporation Return

Sometimes, corporations have different kinds of products which are out-of-date, repair condition, non-functionalities in the working area **[32]**. Because of this, these products lead to decrease corporations' effectiveness and efficiency and they unfavorably affect staff and managers performance in the work area. Therefore, staff and managers cannot perform their work and cannot response to customers' needs. Because they return their products, they make a good relationship with SC firms to get new ones according to their features. Corporation return is also an important opportunity for some big organizations to adjust their new products on the work area because the technology is changing day by day on the work platform while the returning products are collected from SC firms.

2.3.6 Waste Return

A lot of products which are non-repairable, out-of-date, non-functional, etc. are collected in the waste areas. However, these kinds of products can be reusable for producing new products. Therefore, SC firms may use this advantage to collect these products by their vehicles, recycle them and use them in the production of new products instead of using raw materials. In this way, such firms reduce their expenditure for materials and directly focus on how to produce new products by recycling collected old products**[33].**

However, some products cannot be reusable for producing new products in some cases and SC firms should take into account this issue, because some kind of products are just waste **[10].**

2.3.7 End of Lease and Warranty Return

Nowadays, most corporations and firms use leased products, especially technological devices, to perform their work instead of buying these products**[42]**. The aim is to decrease their costs. The reason for leasing is that the life of technological devices is very short because of the rapid technological advances and corporations want to get rid of these products at the right time to get new leased products. Furthermore, such corporations also have some mechanical products and software products, and they want to get rid of these products at the end of the warranty to get new ones **[10].**

By leasing products, most corporations and firms minimize their costs and manage the budget in a good way. When leasing products become obsolete, these corporations and firms

call for leasing firms to collect these devices and bring new technological devices to them **[32].** The reason to return the product at the end of warranty is that the corporations don't want to come across any issue to affect the work performance negatively **[10].**

CHAPTER 3

INFORMATION AND COMMUNICATION TECHNOLOGIES IN SCM

This chapter aims to introduce information and communication technologies used in the SCM. Furthermore, essential ones of them are used in the proposed model, which is given in Chapter 4.

3.1 Information and Communication Technologies in SCM

With the developments in technology, SCM has gained importance in the business area, especially with increasing rate of globalization and global competition **[1]**. Market areas are electronically extended thanks to SCM systems nowadays. This extension involves in the changes of market conditions through the short response time of supply chain operations among supply chain companies and customers via information and communication systems. Information and communication systems in the SCM are used for an effective communication among units related with warehousing, stock management, transportation, deployment, pocketing, supplying the materials and products, and material handlings processes. It means that they control the input and output of products, data management among the SCM processes and provide accessing the data among these processes with technological devices.

Information systems are generally used in the supply chain management as material resource planning, enterprise resource planning and total enterprise integration **[11]**. Material resource planning means that supply chain companies supply the materials and products from different kinds of suppliers whenever they need them with respect to the stock capacity. When materials diminish to a certain level in the stock, related companies supply them by using this planning. Furthermore, the system, through this planning, controls whether the materials and products are in the stock or not. Enterprise resource planning includes in accounting, supplying, manufacturing, stock and warehouse, finance, human resources, sales and deployment, and transportation to maintain the complete supply chain management. Total

enterprise integration provides execution of different kinds of supply chain systems in one system for controlling all operations of the supply chain management.

Information and communication systems in SCM mainly comprise of vehicle tracking system, radio identification systems (RFID), intelligent transport systems, logistic software, customer relationship management system, communication technologies and security technologies, speech recognition, digital imaging, remote management control, 2D Barcode system, portable printing, electronic data interchange, 3D printing, social media and cloud computing **[43]**. These technologies are consecutively explained in detail in the following sections**.**

3.1.1 Vehicle Tracking System

Vehicle Tracking System is used to determine where the exact location of vehicles is by using software collecting vehicle's information with a detailed Picture of vehicles' locations**[55]**. This system is generally comprised of two main technologies which are GPS and GPRS. While GPS is used for locating vehicles through monitoring, GPRS is used for providing communication with drivers in vehicles and authorized individuals through mobile devices. Thanks to these technologies, authorized individuals monitor vehicles' bustles and inform drivers about road situation. Moreover, this system provides drivers to orientate free ways for reducing delivery time in case of traffic conjunctions and jam. In this way, vehicles consume less gasoline during delivery process. In addition to, it provides to protect vehicles against smuggling during transportation time by monitoring them closely. Thanks to this, firms inform police department in case of smuggling.

3.1.2 Radio Frequency Identification Technology (RFID)

RFID system enables supply chain management systems to recognize different kinds of objects more practically through radio frequency which is a wireless technology**[38]**. Companies mainly use these systems in the transportation and shipping activities in SCM as shown in Figure 3.1 because they would like to know vehicles' entrance or exit in locations. Transportation and shipping vehicles have different kinds of chips to monitor them remotely by companies. While these vehicles arrive from/to/depart warehouse, retrieving warehouse, collection area and repair center, they are determined by RFID to enter or exit these locations. The aim of this system is to control whether these vehicles are entering or exiting location. Thanks to this, companies learn the arrival of vehicles or checkout of vehicles.

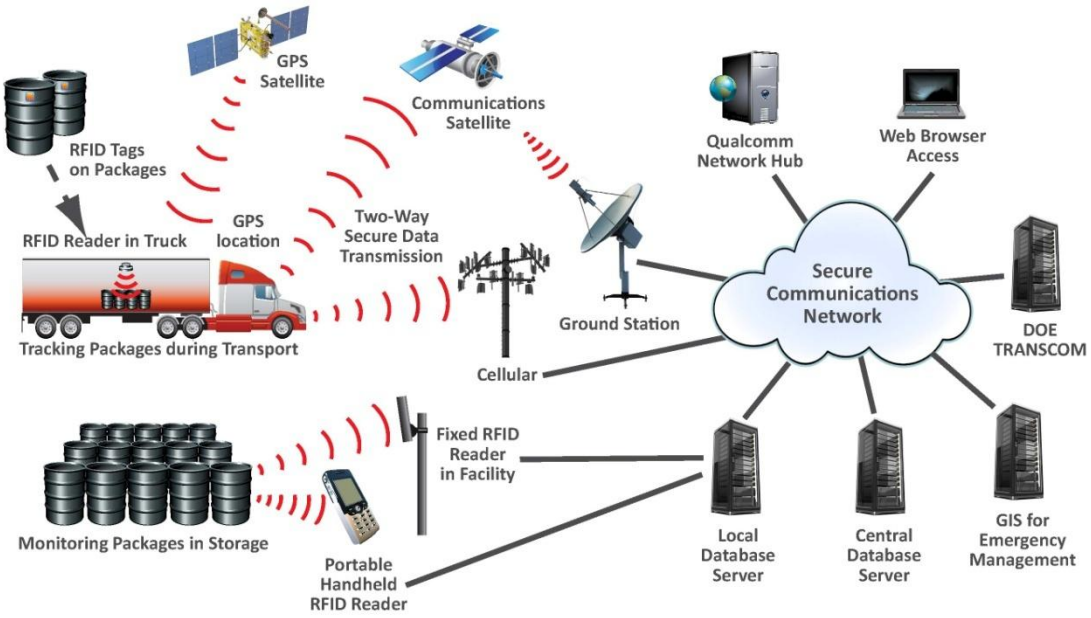


Figure 3.1: RFID System in SC **[39]**

3.1.3 Intelligent Transport System

Intelligent Transport System (ITS) enables companies to control the communication among different kinds of vehicles in the particular locations. It provides coordination of not only road vehicles, but also sea vehicles, planes and trains on routes thanks to the navigation systems. Furthermore, it enables the radio services for communication to give route information to different kinds of vehicles.

ITS consists of four types which are automotive system, railway system, aeronautical and maritime system as shown in Figure 3.2 **[40]**. Automotive system is used for tracking all different kinds of vehicle to communicate with them via wireless system to learn the speeds of vehicles and their locations. Railway system is used for tracking all trains when they are passing through national borders or between locations to learn their speeds and locations. Aeronautical and maritime systems are used for tracking different kinds of air vehicles and sea vehicles to learn their speeds and positions.

Figure 3.2: ITS in SC **[40]**

3.1.4 Logistic Software

Logistic Software used by SC is a desktop and mobile application that controls all SCM activities consisted of freight and transportation, stocking, warehousing, project and budget managements, online services and customer relationship management **[41]**. Logistic Software provides SC companies to control whether products are in stock or not. It also control freight and transportation for coordinating and monitoring different kinds of vehicles on routes and control SC companies' budget to provide a balance between revenue versus expenditures by using graphical interfaces. It also controls project managements for monitoring each SC processes with its time duration. It also has online services to increase the visualization in system to control system easily and provides a relationship between SC companies and customer to meet their needs.

3.1.5 Supply Chain Management System

Supply chain management is generally known as a part of enterprise resource planning system (ERP). Enterprise resource planning mainly controls the accounting, supplying, manufacturing resources, stock and warehousing, finance and human resources, sales and deployment, and transportation to maintain the processes of the supply chain management and to develop a strategic plan to maintain the supply chain management **[1][6][9]**. In addition, it can cover planning and scheduling and customer relationship management **[1][6][9][10].** Accounting system is used for controlling the cost and budget creating tables of revenue and expenditures. Sale management is used for coordinating the sales activities among warehouse, stock, transportation and customer purchasing. Manufacturing and finance are used for controlling the related activities in production area with SC companies' budget. Deployment and Transportation are used for coordinating different kinds of vehicles with products in particular routes and products' deployment among manufacturing areas, warehouses, distribution areas and stores. Planning and scheduling are used for planning each SC activity in time to work smoothly together with other processes. In this way, ERP system enables SC firm to control all SC activities from the starting point to the ending point, and manage them more effectively and efficiency. It provides a good monitoring for efficient management.

3.1.6 Customer Relation Management System

Just as CRM is included in ERP, it can be installed to the SCM as a separate CRM.CRM constitutes processes that occur downstream interaction between corporation and its customers. The objective of CRM provides to generate customer demands and make possible transmissions and trace of orders**[10]**. It means that it provides the flows of the customers' orders, sales and delivery details, information about customers' past orders. Weaknesses can a big issue in CRM when orders cannot be processed and executed effectively and they can leads to result in demand being lost. Therefore, order must be well-defined. The processes of CRM consist of marketing, sell, order management and call center. Marketing process focus on decisions which customers are targeted, how to target customers, what kinds of products are offered to customers and how to price products. With ICT in marketing process, CRM provides analytics improving marketing decisions on pricing and customer and product profitability. Sell process focus on an actual sale to customers. It means that it plans whom to sell and what to sell. Orders from customers are firstly configured in CRM and then appropriate sale is determined. With ICT in sell process, CRM provides

configuration and sale automation. Order Management arranges customers' demands to maintain the influx of orders and trace them effectively. With ICT in order management, orders are traced in every stage of warehouses, distribution areas and stores before reaching products to customers. Call service is a contact between a corporation and its customers to provide help and generate solution about customers' products to them. It also suggests products to products with respect to their purchase. With ICT in call service, CRM makes possible to reduce work done by customer service representatives and route customers to representatives who give solutions and services to customers.

Amazon has a premier role of using ICT to increase its CRM. The corporation customizes products to customers by analyzing their past history and current clicks of their sale**[10]**. The corporation also has quick ordering which make possible one-click orders in the system. The aim of this is to show their orders to customers until their products are delivered to them. Sometimes, call service can be overloaded because of too many calls from customers when they use it. Because of this issue, the corporation has a good callback feature in its CRM to reply customers to solve out their products.

3.1.7 Communication Technologies and Security Technologies

Generally, SC firms use communication technologies such as wireless communication, cellular networks and Bluetooth to share information about all activities instantly **[44]**. However, by the developments in technology, SC companies use different communication technologies as one system rather than many different systems for providing accessibility at any time from any place. Lately, SC companies have started to use mobile devices for providing convenient data access. However, these devices have limited functionalities for monitoring SC processes yet. Therefore, companies generally use desktop and laptop devices. But, by adding new features in SC, mobile devices can be more popular to monitor SC processes in the near future. SC systems need security because they can be dumped and damaged. Unsecure systems may lead to steal some critical information about SC companies by unauthorized individuals from inside or outside. Therefore, SC companies protect their network infrastructure by installing many different kinds of security devices **[44]**. Wireless security mechanisms such as 802.11i, 802.1x, WPA, WPA2, LEAP, FIPS-140, RADIUS servers, VPNs and others can be given as examples. Furthermore, some big security network companies such as Cisco provide SC companies with security devices to maintain the SC management, reliability and security in their infrastructure. These devices provide

functionalities such as hacker and rogue access point detection, user authentication and encryption, integrated firewalls and more. In this way, SC companies protect their own systems against outside attack. Inside attack is also a big problem for SC firms because some staff leak out some confidential information to others or damage some necessary information. Therefore, SC firms install logging system to trace all staff and administrators activities. Moreover, SC companies use some security equipments such as finger printing, door lock system, high definition security cameras to protect unauthorized entrances in warehouses, manufacturing areas and distribution areas **[54]**.

3.1.8 Speech Technology

Speech Technology reduces the needs for users to look at computer displays**[45]**. This technology is widely used by SC companies to share information about activities among SC staff and workers using headphones in warehouse, manufacturing and distribution areas. In this way, staff, administrators and workers get more information about the SC processes and decide what we do next. Speech technology also comprises speech recognition **[44]**. Speech recognition allows authorized staff and workers to enter rooms in warehouse, manufacturing area and distribution area for carrying the products or raw materials on the roof and load them to different kinds of vehicles.

3.1.9 Digital Imaging

Digital Imaging enables SC companies to detect accurate vehicles belonging to companies by capturing their plate for providing accurate delivery while they arrive at warehouse, manufacturing areas, distribution areas and stores. It also gives detailed information about vehicles such as accident reports, recording damages in the transportation and deployment process **[44]**. Thanks to this technology, unofficial vehicles are prevented from entering warehouse, manufacturing areas, distribution areas and stores.

3.1.10 Remote Management Control

Remote management control enables SC companies to control, configure, monitor and troubleshoot barcode readers and printers, RFID equipments, computers, data collection and communication equipment remotely **[44]**. SC network staff and administrators control all activities over the remote control which allows access to SCM system at any time from any place. At the same time, if there is any problem in the system, staff and administrators interfere in system to solve the problem remotely from any place. Staff and administrator can

also update the software on the system remotely. In this way, this control provides SC firms to maintain their competitive advantage against others.

3.1.11 2D Barcode System

2D Barcode System has the ability to trace the bustle of product from one place to another place more easily by recognizing different symbols, symbol sizes and encoded data **[44]**. Although 2D barcode is generally thought as standard to recognize products, most organization especially far east countries sometimes need different kinds of 2D barcode system to identify products because products have different kinds of symbols, symbol sizes and encoded data due to production areas. SC companies determine which products are in the stock or not and which products are in which transportation vehicles thanks to 2D barcode system. Therefore, companies determine stock status and check the flow of the products' activities using 2D barcode system. In addition, when customers buy products at a store, products are determined by 2D barcode system to get information about them. In this way, SC companies can monitor the stock levels in stores and supply their products to the stores from distribution areas according to the decrease at the stock level**.**

3.1.12 Portable Printing

Portable Printing enables SC companies to provide signed delivery receipts, purchase orders, work orders and inspection reports**[44]**. That technology also provides the customer with the documentation that they request from delivery and sale personnel. Furthermore, SC systems keep electronic records about any activities through portable printing and it eliminates paperwork so it reduces the expense of paper. When customers buy products from any store, customer is given the documentation about products with its price and information thanks to portable printing. Because of this, SC firm controls the store activities and check which products are sold and control the revenue and expenditures with respect to these products according to stores' sales. In this way, SC companies can determine the product types and their amounts to be sent to their stores.

3.1.13 Electronic Data Interchange

Electronic data interchange is electronically sharing information among people in separate locations. In SCM, it coordinates all SC activities by providing the flow of information among staff, workers and administrators in electronic environment. Because SCM is a long-term process and each process needs to communicate with others to control

activities and provide flow of information among these activities, SC companies use EDI communication method**[46].**

EDI provides the detail information about each activity with its time period and it leads to eliminate the gap among suppliers, customers and SC companies supporting communication with each other. In this way, SC users get necessary information about the stages of activities, transportation used for deployment, products stored in warehouses, suppliers of raw materials for producing new product and customers' needs. **[47].**

Nowadays, because EDI provides the influx of information in each stage of SC activity, it is widely used by staff, workers, and administrators to learn about what each stage is and how it works. However, there can be a communication and update problem when the internet connection is cut off. Therefore, SC companies should update and configure settings in EDI in particular time to communicate with staff, workers, and administrators without encountering any problem while SC process is continuing **[48]**.

3.1.14 3D Printing

Nowadays, most documents are delivered as a 2D printing included in any drawings on the paper in the SCM processes. With the developments in technology, customers' demand is getting more and more complex and they would like to see their products visually. Therefore, many companies are now developing 3D printing and trying to add it in SC processes**[49]**. 3D printing enables product creation by means of obtaining powdered substances such as metals and ceramics. In this way, customers can see their products as a 3D dimensional prototype and get much more information about products. This technology provides their customers with streamlined logistic model, customer-managed inventory, 3D printing hub and Home 3D printing. Streamlined logistic model means enabling to flick through the product before it is delivered or shipped, and reduce the inventory levels and warehousing requirements. Customer-managed inventory means that customers create their own 3D printing prototype then they send it to suppliers to produce their own model. 3D printing hub means that some SC companies provide their customers to draw some 3D dimensional models for their demands. Home 3D printing means that some SC companies allow their customers to draw their models themselves by providing different kinds of 3D printing.

Although 3D printing is used in the SC processes, it supports only 30 percent of the finished product, but it will provide all percent of the finished product in the future **[50]**.

3.1.15 Social Media

Social media provides SC companies to communicate with workers, staff and administrators in each SC process and it leads to increase effectively all SC processes thanks to communication. By increasing to use the social media day by day, SC companies and customer check the control of the process and get information about what any process is doing by means of social media tools such as Twitter, Facebook, instant messaging applications and others**[50]**. Furthermore, SC companies can attract many different kinds of customers in any part of the world to present and share their activities and products in the social media.

Upon social media, there is an increasing communication among customers, and they can share their opinions with each other. This situation forces companies to find solutions for problems by using SCM more effectively. At the same time, it also contributes positively on global trade.

Some big SC companies have already started to use this technology and it will be widely used in the future.

3.1.16 Cloud Computing

Cloud computing in SC is that SC companies generally monitor customers' demands and SC activities using different kinds of online portable devices to cope with the large scale complexity of global supply chain which requires accessing at any time from any place **[51]**.

Because SC is getting more and more complex, SC companies have started to use cloud computing technology **[52]**. With the development of technology, SCM systems include in many different kinds of systems put together to form a single, but complex system. Therefore, SC companies purchase appropriate applications as "software as a service" for their requirements, and in this way, they reduce the number of problems that they may come across, and also they reduce the expenses. Furthermore, SC companies create their IT infrastructure as a cloud to manage and monitor all SC processes. Their cloud applications involve in dashboards consisting of input and output of products in warehouses and distribution areas, vehicles information with their plate numbers, positions, gasoline capacity, and graphics showing the capacity of warehouse, manufacturing and distribution area. In this

way, SC companies reduce their outlay on the systems and increase the flow of information among their activities and cloud computing enables SC companies to provide competitive advantage against other companies if that technology is used in a right way to monitor all activities of SC processes.

This technology is rarely used by SC companies nowadays, but they endeavor to adapt it in the future for maintaining their competitive advantage against other companies.

CHAPTER 4

PROPOSED RSCM MODEL WITH ICT TECHNOLOGIES

In this chapter, a SCM system having RSCM capabilities is modeled emphasizing ICT usage in it. Then, 3 RSCM processes which are modeled using sequence diagrams of UML are explained. These processes are:

- Customer Return
- Out of date Product Return
- Repair and Non-Repair Situation Return

The reason to select these three processes is that they are common return types in SCM and companies are generally come across these processes in the work area. Moreover, these processes are general issues in the reverse supply chain for companies to have an effective RSCM because customers mainly return their products in the scope of these three return processes **[9][10][15]**.

Before explaining RSCM, some introductory information about sequence diagram is given below.

4.1 Sequence diagram of UML

Sequence diagram illustrates the collaboration of entities depended on a consecutive time line and show how entities interact with each other in a particular sketch of use case **[53]**. Although this diagram uses many notations to illustrate different concepts, some essential notations are used to explain each RSCM activities. These are actor, lifeline, message, recursive message and loop combined frame, which are explained in Table 4.1.

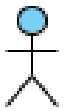
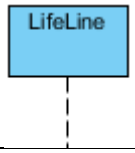
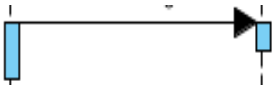
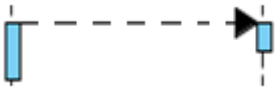
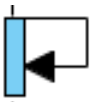
	Actors interact with entities and represent roles of human users, external hardware or other uses.
	Lifeline is used to represent an individual participant/entity/role in interaction.
	Message defines a particular communication between lifelines of an interaction. A message with straight line is used to show information influx between lifelines and actor.
	Message defines a particular communication between lifelines of an interaction. A flow with dashed line is used to show material influx between lifelines and actor.
	Self message represents the self invocation of a lifeline.
	Combined fragment is an interaction fragment which defines a combination (expression) of interaction fragments such as alternatives, options, iteration, etc.

Table 4.1: Notations used in Sequence Diagrams

Notice that material flows are represented with dashed lines and information flows via different information technologies are shown as straight lines.

4.2 Proposed RSCM Model with ICT Technologies

In this study, we assume existence of a SCM System supported by ICT. This system already includes forward SC activities and these activities are out of scope of this study. It also comprises reverse SC activities. However, we illustrate three of the RSCM processes with ICT technologies in this thesis. The other reverse processes can be extended in a similar way. The essential information and communication technologies and systems are integrated to the SCM system. These technologies and systems are RFID technology, CRM system, social media systems, 2D barcode technology, cloud services, e-mail server, digital imaging technology, speech recognition technology, vehicle tracking system and ERP system. Bank is used for money transactions between firm and customers. The proposed SCM system with these essential technologies and systems is shown in Figure 4.2.

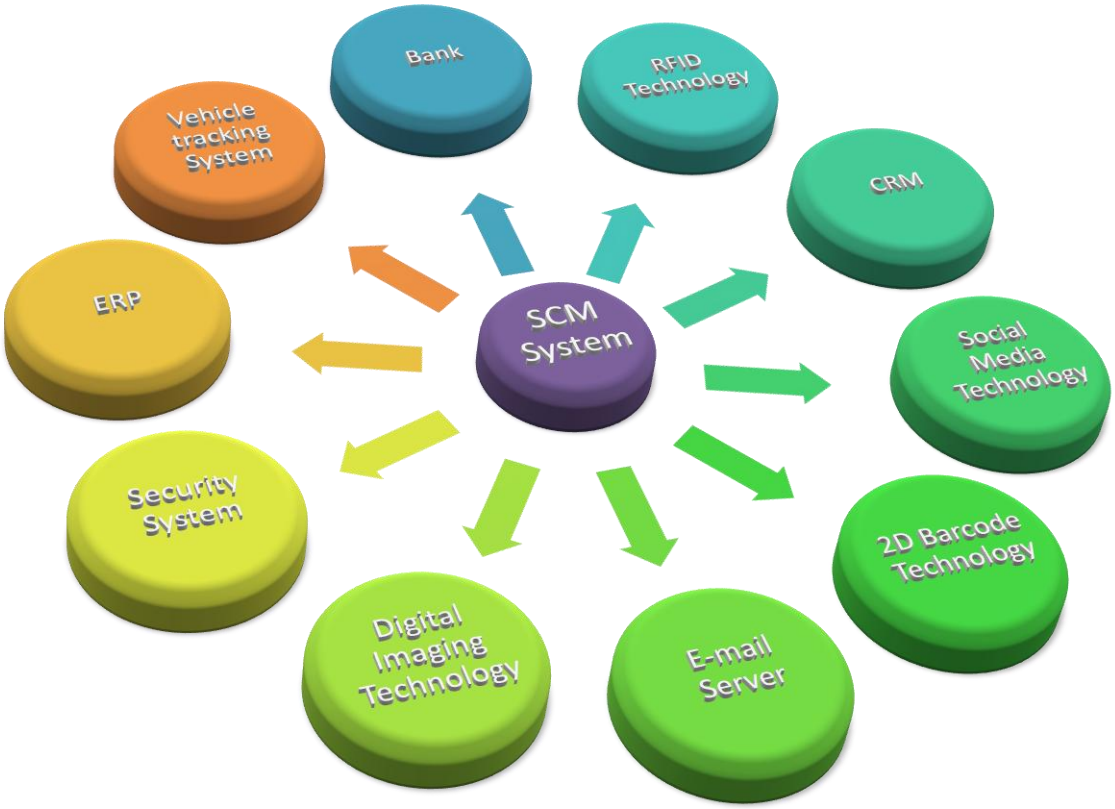


Figure 4.2: Proposed SCM System with essential I&C technologies

The main role of this proposed system is to coordinate the activities of RSCM in addition to FSCM while customers return and retrieve their products for different reasons. This system also helps to understand 3 processes of RSCM by using sequence diagrams given in the next section. The main components of the system and other collaborating systems are explained below.

Main system (SCMS): The main system consists of modules to perform all the functionalities required in FSCM and RSCM. The system is extended with some information technologies such as RFID and digital imaging technologies as illustrated in figure 4.2. In addition, the system is integrated with internal (such as CRM system).

Nowadays, there are different kinds of functions that a main system needs and it is too expensive to integrate all these functions into the main system for companies. Moreover, it is hard to install complex software, servers, database, bandwidth and required infrastructure and manage them. At the same time, many diverse team workers are needed to manage the main system. However, because of the coordinating problems among a large team, when the system has error issues, they can blame each other to solve out the problems. When new updates of existing software appears, they must be installed by authorized individuals, but they can lead to ravage the main system because of the discrepancy of software versions and authorized individuals. Therefore, we assume a main SCM system installed on a cloud platform and it works in mutual data centers. With the cloud platform, the main system is more scalable, more secure, and more reliable than establishing on-premise systems with complex software, servers, database, bandwidth and infrastructure. Moreover, new versions of existing software are automatically updated because of cloud's feature. Because the main system is on the cloud platform, it is thought as IaaS. It means that essential software and hardware required for the SCM system is provided by a service provider. Financial management is also provided with an integration to bank systems for funding or refunding money between the firm and customers. Then, the SCM system is installed by the company itself.

Although the main system is integrated to other systems and uses different technologies, the main system has just only one interface and anyone use it to deal with his/her work with respect to his/her work area. Since the reverse activities of SCM are implemented in the main system, users can access RSCM activities on the main system. During a reverse SCM activity different technologies and systems can be used in an integrated way such that users always feel they use the same system. The systems and technologies used together with the main

system are explained below just considering RSCM activities. Note that the same systems and technologies are also used for FSCM activities. However, since our focus is on the RSCM, here we emphasis the RSCM activities.

Bank: This system is used for money transactions for providing money return from firm to customers in customer return situation. It means that the firm refunds money to customers' credit card or bank account.

RFID Technology: RFID technology is planned in this proposed system to trace companies' vehicles. When vehicles depart/arrive from/to warehouse, retrieving warehouse, collection area and repair center, that information can be collected automatically using RFID technology and transferred to the main system.

CRM: Because CRM is used to manage the relationship between companies and customers, it must be used together with the SCM system. We assume a CRM system integrated to the main system. Customers register to the CRM system of companies and then login to the system using their ID and password. For RSCM activities, the CRM system supports related functionalities. For example, when a customer wants to start a return process for any reason, he can do this online from his house using the CRM system.

Social Media Technology: Social media systems such as Twitter and Facebook can be used especially to inform customers about RSCM activities such as getting their returning products, repairing products or new products. When customers register to the CRM system, they can fill their social media addresses and then these addresses can be used for communication on the social media. To achieve that the SCM system should be integrated with the related social media systems. We assume that social media is especially used to inform customers. For example, in product return process, authorized personnel inform customers about getting products via social media. As another example, before sending new products or repaired products to customers, authorized personnel inform customers via social media.

2D Barcode Technology: 2D Barcode technology provides determination of products and accessing to their essential information. Each product is produced with a 2D barcode and it becomes inseparable part of the product. Then, it is possible to track all activities done for a product during its life cycle. In RSCM, 2D barcodes can be used again to track the flow of products. For example, when vehicles arrive at customers' addresses taken from the CRM

system, staff get customers' products and determine them via 2D Barcode System. Then, this information is automatically transferred to the main system.

E-mail server: E-mail system is accepted as a communication technology between authorized personnel and customers. It can also be used sometimes for company internal communication or company-to-company communication. If customers prefer to use e-mail for communication, then the company has to use it to communicate with the customer. To achieve this requirement, the e-mail server has to be integrated with the main system. For example, customers can be informed about delivering new products or repaired products, and getting their returning products.

Digital Imaging Technology: This technology helps companies for security in the proposed system. Only authorized vehicles are permitted to enter warehouse, retrieving warehouse, collection area, and repair center. Vehicles' information with their plate number is put in the system in advance. When a vehicle arrives at a restricted area, its digital image is taken and analyzed automatically. If vehicle plate number (and view of vehicle) matches with the ones in the database, then it is allowed to enter to the restricted area such as warehouse, retrieving warehouse, collection area and repair center.

Security System: Speech recognition technology is used for security in this SCM system. We assume that there are different departments in warehouse, retrieving warehouse, collection area and repair centers and only authorized staff are allowed to these departments. Therefore, we need a security system and we use speech recognition for this purpose. When an authorized person wants to enter a restricted room, he can use his voice for authorization to enter inside. If his voice matches with the voice recorded before, then the system gives permission for entrance. Although we use voice for user identification and verification here, other biometric information such as fingerprints or tokens can also be used for the same purpose.

ERP: Although ERP comprise many activities as mentioned in Chapter 3, we only use accounting and scheduling functionalities in this proposed system. Related staff uses accounting to determine available budget and cost of activities required for RSCM processes. They use scheduling for learning existing schedules and to plan RSCM activities. For example, related staff can check repair program of the repair center and can determine possible repair date of a product and accordingly inform the customer.

Vehicle Tracking System: we presume that GPS is used for monitoring vehicles of transportation and GPRS is used for making data communication between authorized individuals in the firm and drivers in the vehicles to give information about transportation.

4.3 Customer Return

In this section, we model one of the RSCM processes, namely customer return, using sequence diagram. This RSCM process represents the case in which customers want to return their products because of different reasons. The reason to return may be one of the following:

- **Customers' personal needs:** Customers buy products, but these products cannot respond to their personal needs because of performance problem or non well-work, and they return back them.
- **Customers' family and work structure**: Customers buy products, but they are affected negatively by their family and colleagues to return back them.
- **Technological advances:** Customers buy products, but these products erode in time quicker than normal lifetime and they return them.
- **Discontent of customers:** Customers buy products, but they dislike the products because of their brand names, structures, shapes, usage, etc. in time. Therefore, they want to return their products **[15]**.

This RSCM process consisting of 28steps is illustrated in Figure 4.3 using sequence diagram. The 28 steps are explained one by one giving special emphasis on ICT technology usage on these steps.

1) call_Firm

First of all, because customers want to return their products, they apply to firm using the CRM system of the firm via electronic or mobile devices by filling essential information of a form involved in the CRM system. This information includes also an explanation about why they return their products.

2) firm_Process

Authorized firm personnel who are responsible for checking forms analyze and assess these forms to decide why customers return their products and then they inform their top

managers to get their online approval on the SCM system. Then, the managers give feedback to the authorized personnel to start the retrieving process to get products and money returns via the SCM system. Then, authorized personnel enter this process with timeline by accessing ERP from the main system for scheduling.

3) feedback_Cus

After the firm process is completed, authorized personnel inform customers to start the retrieving process to get their products through e-mail or social media depending on the customer preferences on the CRM system.

4) call_Trans

Authorized personnel in the firm inform authorized personnel in the transportation department/company about customers, whose products should be taken back with their addresses. If transportation is done by department of the same company, information can be sent directly using related module of the SCM system. E-mail can be used in case the SCM system does not support such functionality.

5) trans_Process

Authorized personnel in the transportation department/firm check vehicles list in the main system and determine appropriate vehicles to be sent to customers and then inform their top managers about this issue to get their approval through the SCM system. Then, managers give feedback to the authorized personnel to send vehicles to get customers' products.

6) inform_Cus

Before vehicles are sent, authorized individuals in the transportation department/firm inform customers about their products return and to arrange an appropriate delivery time through e-mail, social media or phone.

7) get_Product

Authorized personnel in the transportation firm inform transportation staff and then vehicles set out to customer addresses for getting their return products. The phases of transportation are traced through vehicle tracking system. While getting customer products, staff uses the 2D barcode system to recognize the products and send this information to the main system.

8) return_Back

After getting products from the customers, staff returns back to the transportation firm. Meanwhile, authorized personnel can trace the vehicles through vehicle tracking system to track vehicle activities. Finally, the vehicles arrive at the transformation firm.

9) ret_wareProcess

When the vehicles arrive at the retrieving warehouse, the system uses digital imaging to recognize the vehicles plate numbers for checking whether these vehicles belong to the transportation firm and then give permission to enter the retrieving warehouse. Moreover, when the vehicles enter the retrieving area, RFID checks their entrance and sends information to the main system. Then, staff brings down the products from vehicles and recognizes these products through 2D barcode technology upload this information into cloud service and place them at the shelves in the rooms of warehouse by giving entrance permission via speech recognition. Then, staff control whether these products are unbroken or undamaged.

10) inform_Firm

After staff in warehouse determines products to be used on return process, they inform authorized personal about this issue through SCM. Then, authorized personal inform related personal about starting return process based on customers' product status which are unbroken or undamaged through SCM.

11) return_Back

After these products are placed to the shelves in the retrieving warehouse, the vehicles depart to go back to the transportation firm. This travel can also be traced with sending road information by the authorized personnel of the transportation firm by using vehicle tracking system.

12)inform_Cus

Authorized personnel in firm inform customers about refunding money to their credit card or bank account through e-mail or social media.

13) begin_Trnsn

Authorized personnel in firm begin money transaction via the bank for refunding through financial management in cloud.

14) commit_Trnsn

Transaction from authorized personnel in firm is committed by bank to ready for refunding.

15)return_Mon

Authorized personnel in firm enter firm's account number and customers' orders based on their credit card or bank account and refunds money to their credit card or account.

16) inform_Firm

When the capacity of retrieving warehouse is filled or when there are certain amount of returned products, the authorized personnel in the retrieving warehouse inform the authorized personnel in the firm about delivery of these products to the collection area through the SCM system.

17) call_Trans

Upon the manifesto from retrieving warehouse, the authorized personnel in the firm inform the authorized personnel in the transportation firm about departure of the vehicles to the retrieving warehouse to deliver these products to the collection area through the SCM system.

18) inform_Ware

Before vehicles are sent, authorized personnel in the transportation firm inform the authorized personnel in warehouse about the arrival of vehicles to warehouse through the SCM system.

19) go_to_Destination

The authorized personnel in the transportation firm order the transportation staff to set out. Then, some vehicles go to the retrieving warehouse and this transportation situation is traced through vehicle tracking system. Finally, they enter the retrieving warehouse by getting entrance permission via digital imaging in retrieving warehouse.

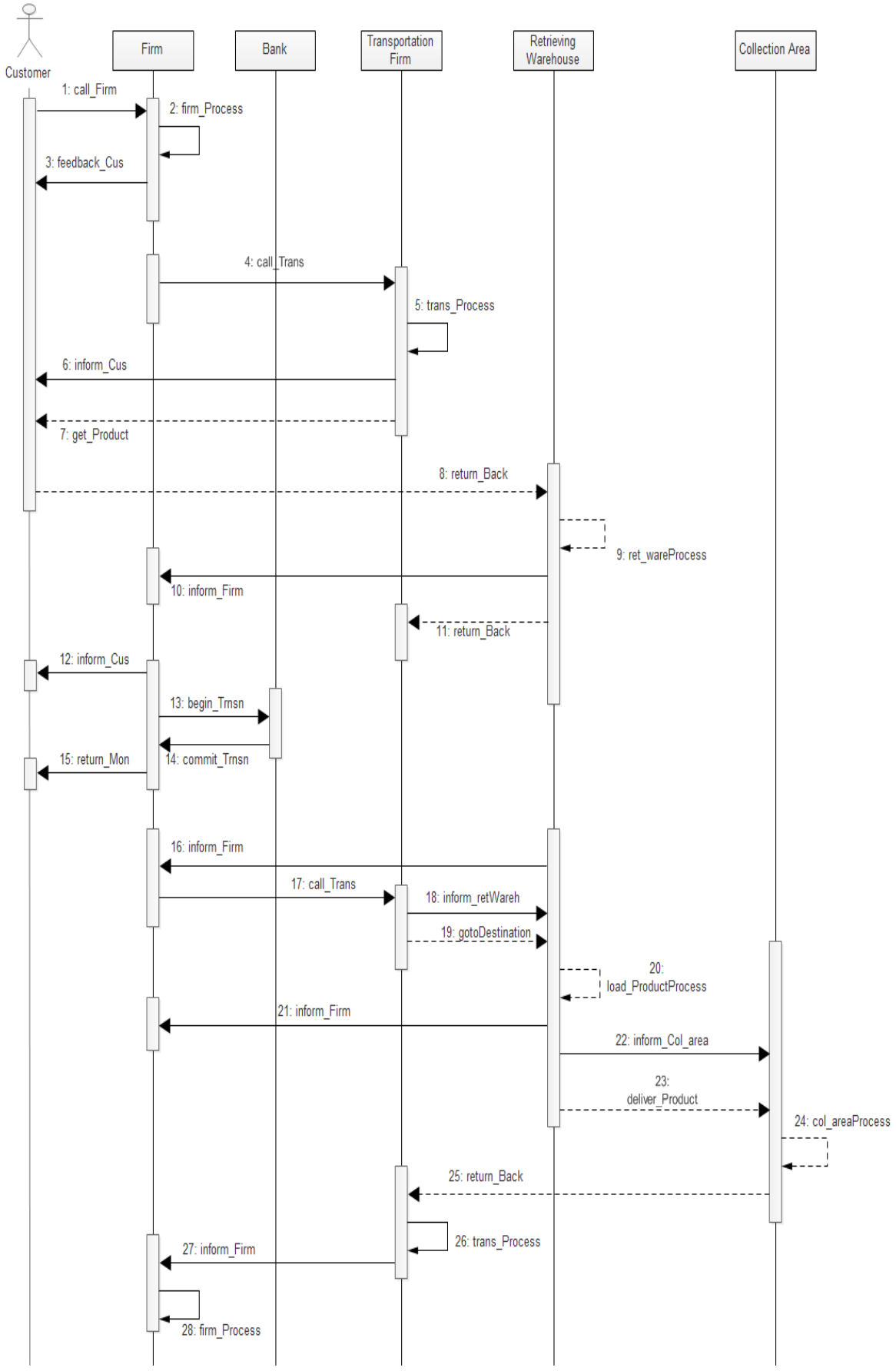


Figure 4.3: Sequence Diagram for Customer Return

20) load_ProductProcess

After the vehicles enter the retrieving area, RFID checks their entrance and send information to the main system. Then, staff in the retrieving warehouse takes products from shelves in different kinds of rooms by getting entrance permission via speech recognition and load them to vehicles. Moreover, products are read via 2D barcode to determine how many they are in vehicles.

21) inform_Firm

After loading products into vehicles in the retrieving warehouse, the authorized personnel in the retrieving warehouse inform the authorized personnel in the firm about loading process of returned products through the SCM system.

22) inform_Col_area

After loading returned products into vehicles in the retrieving warehouse, the authorized personnel in the retrieving warehouse also inform the authorized personnel in the collection area about the departure of these vehicles with a large number of return products and send their plate numbers information to the collection area through the SCM system.

23) deliver_Product

Upon the manifesto of collection area, the authorized personnel in the transportation firm inform transportation staff, and then vehicles set out to the collection area to deliver returned products. This transportation situation can be traced through vehicle tracking system.

24) col_areaProcess

When these vehicles arrive the collection area, the authorized personnel in the collection area use digital imaging to recognize the vehicles' plate numbers for checking whether these vehicles belong to transportation firm and then give permission them to enter to the collection area. Moreover, when the vehicles enter the retrieving area, RFID checks their entrance and send information to the main system. Then, staff brings down the products from vehicles and recognizes these products through 2D barcode technology, upload this information into cloud service and place them at the shelves in the rooms of warehouse by giving entrance permission via speech system.

25) return_Back

After these products are placed at the shelves in the collection area, the vehicles depart to go back to the transportation firm. This travel is traced from the authorized personnel in the transportation firm through vehicle tracking system to check whether the vehicles are on the right way.

26) trans_Process

After the arrival of vehicles in the transportation firms, the authorized personnel in the transportation firm control vehicle conditions which are fuel capacity, arrival time from retrieving warehouse to transportation firm, damage conditions and range before going somewhere through the SCM system.

27) inform_Firm

After vehicles get back to the transportation firm, the authorized personnel in the transportation firm inform the authorized personnel in the SC firm about the completion of the process.

28) firm_Process

After the process is completed, authorized personnel use ERP in the SCM system to enter accounting for register the cost of returning process and check how this process takes via schedule.

4.4 Out-of-Date Product Return

In Figure 4.4, the case in which customers want to return their products because they are out-of-date is illustrated in the sequence diagram. In this case, customers want to return products and demand new products which are equivalent of the old ones from firms **[15]**.

The process consisting of 24 steps is illustrated in Figure 4.4 and the activities are explained below in detail.

1) inform_Cus

The authorized personnel in firms inform customers about their products' status which is out-of date through e-mail or social media. Since the life of products is tracked by the system, the related personnel is aware of that situation and starts this return process.

2) Cus_Process

Upon getting information from firms, customers apply CRM to start process by which old products are got back by firms and new products are sent to customers at the same time by filling essential information in CRM.

3) feedback_firm

After filling necessary information, customers give feedback about acceptance of process to the authorized personnel in firms.

4) firm_Process

According to information from customers, authorized personnel who are responsible for checking forms analyze and assess these forms to decide continuation of the process, later they inform their top managers to get their approval. Then, these managers give feedback to the authorized personnel to start the retrieving process. Then, authorized personnel enter this process with timeline to the ERP for scheduling.

5) inform_Ware

After firm process is completed, the authorized personnel in firm send information about checking customers' new products which replace returned ones through the SCM system to the authorized personnel in warehouse.

6) ware_Process

Upon information from firms, the authorized personnel in warehouse check customers' products in warehouse through cloud service to find these products.

7) feedback_firm

After reservation of customers' new products, the authorized personnel in warehouse give information about customers' new products to the authorized personnel in firms through the SCM system.

8) firm_Process

Upon information from warehouse, the authorized personnel in firms inform other personnel and managers about customers' new products in warehouse through the SCM system.

9) call_Trans

Authorized personnel in the firm inform authorized personnel in its transportation firm about departure to warehouse according to customers' products through the SCM system.

10) trans_Process

Authorized personnel in the transportation firm check vehicles in the list in the main system that they have created before and determine vehicles to be sent to warehouse, then, they inform their top managers about this issue through the SCM system. Then, managers give feedback to the authorized personnel to send vehicles to get customers' products in warehouse through the SCM system.

11) inform_Ware

Before vehicles are sent, authorized personnel in the transportation firm inform the authorized personnel in warehouse about the arrival of vehicles to warehouse through the SCM system.

12) go_to_Destination

The authorized personnel in the transportation firm order the transportation staff to set out through the SCM system and then vehicles set out and go to the warehouse and this transportation situation is traced through vehicle tracking system to check whether the vehicles are on the right way and then provide to arrive the warehouse by sending the road situations from the authorized personnel in the transportation firm.

13) ware_Process

When these vehicles arrive the warehouse, authorized personnel in the warehouse use digital imaging to recognize the vehicles plate numbers for checking whether these vehicles belong to the authorized transportation firm then give permission them to enter the warehouse. Moreover, when the vehicles enter the retrieving area, RFID checks their entrance and sends information to the main system.

14) inform_Cus

The authorized personnel in the firms send information to customers though e-mail or social media about when the returned products will be taken and new products will be delivered to customers.

15) feedback_Trans

Upon information from transportation firms, customers give a feedback about time information of delivery to the authorized personnel in transportation firm through e-mail or social media.

16) inform_Ware

Upon information from customers, the authorized personnel in transportation firms give information about products to be delivered to customers and delivery time to the authorized personnel in warehouse through the SCM system.

17) ware_load_Process

Upon information from transportation firms, the staff and workers in warehouse take products from shelves in different kinds of rooms by getting entrance permission via speech system and load them to vehicles. Moreover, products are read via 2D barcode to determine how many they are in vehicles.

18) get_outofdate_Product&deliver_new_Product

After loading process, vehicles go to the customers to get out-of-date products and deliver new products at the same time through vehicle tracking system. After getting their returned products, staff in vehicle uses the 2-D bar-code system to recognize products to be delivered and returned and sends this information about products to the firm through the SCM system.

19) return_Back

After getting returned products from customers, vehicles with returned products get back to the retrieving warehouse. This process is traced through vehicle tracking system.

20) ret_Wareh_Process

When these vehicles arrive at the retrieving warehouse, authorized personnel in the retrieving warehouse use digital imaging to recognize the vehicles plate numbers for checking

whether these vehicles are right ones and then give permission to enter the retrieving warehouse. Moreover, when the vehicles enter the retrieving area, RFID checks their entrance and send information to the main system. Then, staff brings down the products from vehicles and recognizes these products through 2D bar-code technology, upload this information into cloud service and place them at the shelves in the rooms of warehouse by giving entrance permission via speech recognition.

21) return_Back

After these products are placed at the shelves in the retrieving warehouse, the vehicles depart to go back to the transportation firm. This travel is traced from the authorized personnel in the transportation firm through vehicle tracking system to check whether the vehicles are on the right way.

22) trans_Process

After the arrival of vehicles in the transportation firms, the authorized personnel in the transportation firm control vehicle conditions which are fuel capacity, arrival time from retrieving warehouse to transportation firm, damage conditions and range before going somewhere by using the main system.

23) feedback_firm

After the returning of these vehicles from the retrieving warehouse to transportation firm, the authorized personnel in the transportation firm inform the authorized personnel in the firm about the completion of the process through the SCM system.

24) firm_Process

After the process is completed, authorized personnel use ERP to enter accounting for register the cost of returning process and check whether the process is completed according to the schedule.

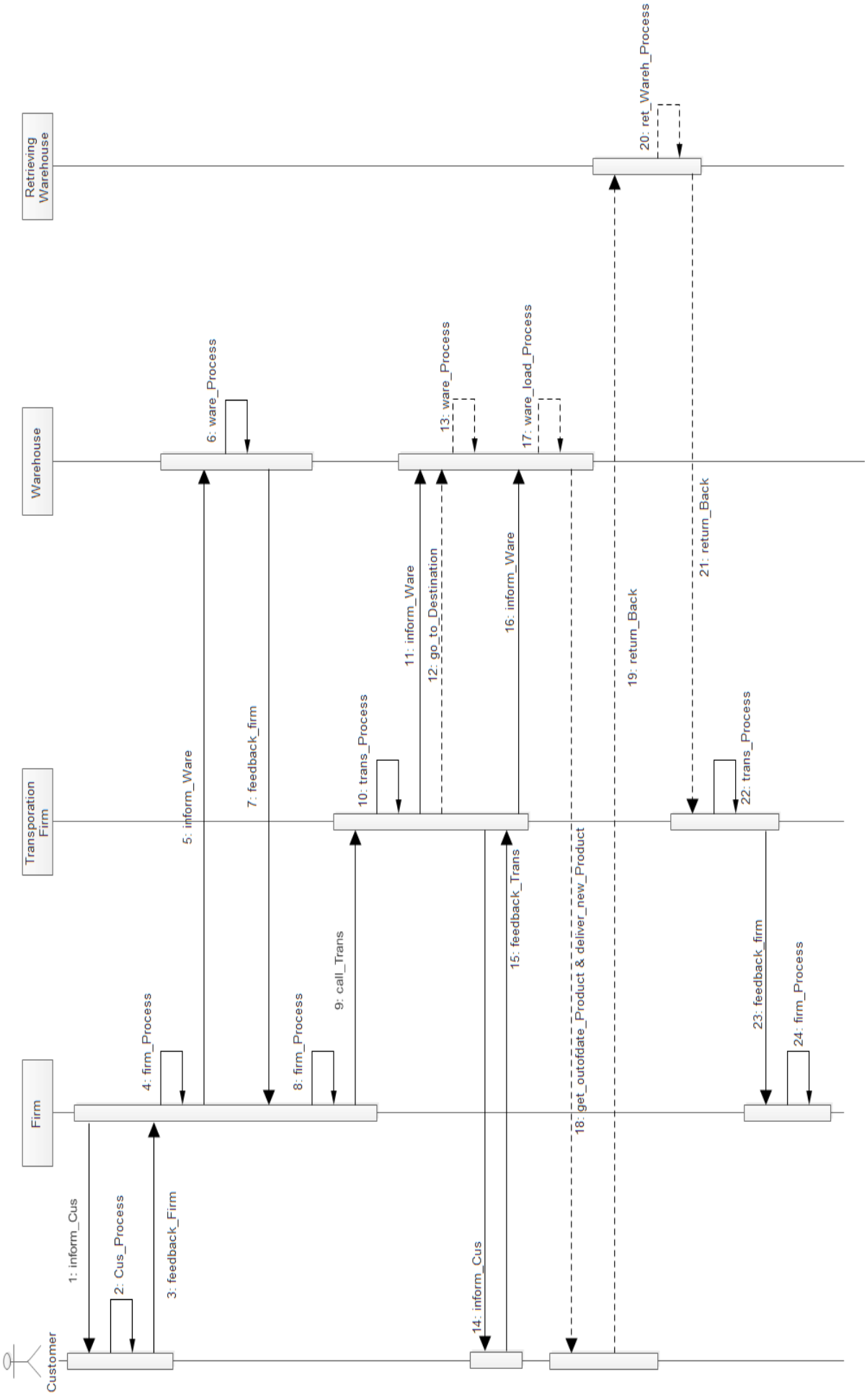


Figure 4.4 : Out of Date Product Return

4.5 Repair and Non-Repair Situation Return

This return process comprises 2 types which are repair and non repair situation. In repair case which is shown in Figure 4.5, customers demand to return their products for repairing because their products are broken After the repair process, the same product are delivered to the customers**[15]**. In non repair situation shown in figure 4.6, customers demand to return their products for repairing because their products are broken. However, the products cannot be repaired because of different reasons**[15]**.

Repair Situation Return

1) call_Firm

First of all, when customers want to return their products, they apply CRM of firm via electronic or mobile devices by filling essential information of the forms involved in CRM. This information comprises the returned products with their returning reasons.

2) firm_Process

According to information from customers, authorized personnel who are responsible for checking forms analyze and assess these forms to decide why customers return their products to repair them, then; they inform their top managers about customers' request. Then, these managers give feedback to the authorized personnel to start the retrieving process through the SCM system. Then, authorized personnel start this process with a schedule using the ERP system accessed from the main system.

3) feedback_Cus

After firm process is completed, the authorized personnel in the firms inform customers about getting products through e-mail or social media.

4) call_Trans

Authorized personnel in the firm inform authorized personnel in its transportation firm about which customers' products will be collected with their addresses information through the SCM system.

5) trans_Process

Authorized personnel in the transportation department/firm check vehicles list in the cloud platform and determine appropriate vehicles to be sent to customers and then inform their top managers about this issue to get their approval through the SCM system. Then, managers give feedback to the authorized personnel to send vehicles to get customers' products through the SCM system.

6) inform_Cus

Before vehicles are sent, authorized personnel in the transportation firm inform customers about when their products will be taken through e-mail or social media.

7) feedback_Trans

Customers give feedback to the authorized personnel in the transportation firm about delivery time through e-mail or social media.

8) get_Product

Upon the demand from customers, authorized personnel in the transportation firm inform transportation staff through the SCM system and then vehicles set out to customer addresses for getting their return products. The phases of transportation are traced through vehicle tracking system. After getting customer products, staff uses the 2-D bar-code system to recognize the products and send these information to company.

9) return_Back

After getting returned products from customers, vehicles with returned products get back to the repair center. This process is traced through vehicle tracking system.

10) repair_Process

When vehicles arrive the repair center , authorized personnel in the repair center use digital imaging to recognize the vehicles plate numbers for checking whether these vehicles belong to the authorized transportation firm then give permission them to enter repair center. Moreover, when the vehicles enter the retrieving area, RFID checks their entrance and send information to the main system. Then, staff brings down the products from vehicles and recognize these products through 2D bar-code system, upload this information into cloud

service and place them at the shelves in the rooms of warehouse by giving entrance permission via speech system.

11) return_Back

After bringing breaking products at the repair center, vehicles get back to the transportation firm. This process is traced through vehicle tracking system.

12) inform_Firm

After the arrival of vehicles at the transportation firm, the authorized personnel in the transportation firm inform about the completion of transporting repairing products to the authorized personnel in the firm through the SCM system.

13) repair_Product

This process is shown to repair products.

14) inform_Firm

After repair process is completed, the authorized personnel in the repair center inform the authorized personnel in the firm to get products through the SCM system.

15) inform_Trans

Upon information retrieval from repair center, the authorized personnel in the firm inform the authorized personnel in the transportation firm about departure to repair center to get repairing products through the SCM system.

16) trans_Process

Before departure starts, authorized personnel in the transportation firm check vehicles in the list in the main system which they created before and determine which vehicles to be sent to repair center, and then, inform their top managers about this issue through the main system. Then, managers give feedback to the authorized personnel to send vehicles to get customers' products through the SCM system.

17) inform_Repair

Before vehicles are sent, authorized personnel in the transportation firm inform the authorized personnel in repair center about the arrival of vehicles to repair center through the SCM system.

18) go_to_Destination

The authorized personnel in the transportation firm order the transportation staff to set out through the main system and then vehicles set out and go to the repair center and this transportation situation is traced through vehicle tracking system to check whether the vehicles are on the right way.

19) repair_Process

When these vehicles arrive at the repair center, authorized personnel in the repair center use digital imaging to recognize the vehicles plate numbers for checking whether these vehicles belong to transportation firm, and then, give permission them to enter the repair center. Moreover, when the vehicles enter the retrieving area, RFID checks their entrance and sends information to the main system.

20) inform_Cus

When the authorized personnel in the transportation firms learn that the products are repaired and ready for delivery, they send information to customers though e-mail or social media to determine a delivery time.

21) feedback_Trans

Upon information from transportation firms, customers give a feedback about delivery time to the authorized personnel in transportation firm though e-mail or social media.

22) inform_Repair

Upon information from customers, the authorized personnel in the transportation firm inform the authorized personnel in the repair center about which vehicles with repairing products are sent to which customers through the SCM system.

23) repair_Load

Upon information from transportation firms, the staff and workers in repair center take products from shelves in different kinds of rooms by getting entrance permission via speech recognition and load them to vehicles. Moreover, products are read via 2D barcode to determine how many they are in vehicles.

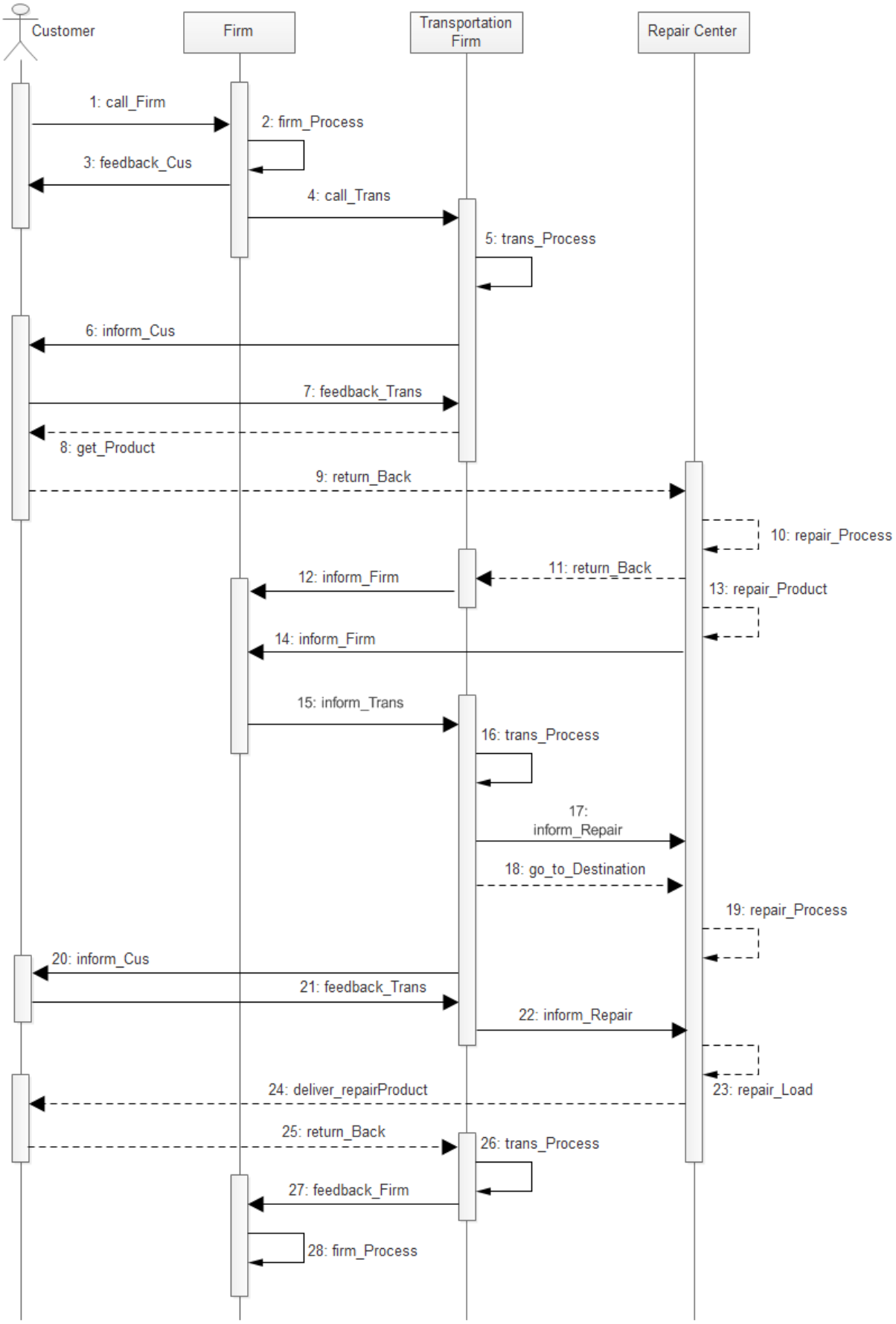


Figure 4.5: Repair Situation Return

24) deliver_repairProduct

After loading process, vehicles go to the customers to deliver their repairing products through vehicle tracking system. When staff delivers products to customer, they give information about the completion of delivery process through the SCM system.

25) return_Back

After staff in vehicles delivers repaired products to the customers, vehicles get back to the transportation firm. This process is traced through vehicle tracking system.

26) trans_Process

After the arrival of vehicles in the transportation firms, the authorized personnel in the transportation firm control vehicle conditions which are fuel capacity, arrival time from retrieving warehouse to transportation firm, damage conditions and range before going somewhere by the main system.

27) feedback_Firm

After vehicles return back transportation firm, the authorized personnel in the transportation firm inform the authorized personnel in the firm about the completion of the process through the SCM system.

28) firm_Process

After the process is completed, authorized personnel use ERP to enter cost of returning processand check compliance of activities to the schedule.

Non-Repair Situation Return

1) call_Firm

First of all, when customers want to return their products, they apply CRM of firm via electronic or mobile devices by filling essential information of the forms involved in CRM. This information comprises the returned products with their returning reasons.

2) firm_Process

According to information from customers, authorized personnel who are responsible for checking forms analyze and assess these forms to decide why customers return their

products to repair them, and then they inform their top managers about these products from customers by using the main system. Then, these managers give feedback to the authorized personnel to start the retrieving of the process through the SCM system. Then, authorized personnel enter this process with timeline to the ERP in the main system for schedule.

3) feedback_Cus

After firm process is completed, the authorized personnel in the firms inform customers about getting products through e-mail or social media.

4) call_Trans

Authorized personnel in the firm inform authorized personnel in its transportation firm about which customers' products will be collected with their addresses information through the SCM system.

5) trans_Process

Authorized personnel in the transportation firm check vehicles in the list in the cloud service which they created before and determine which vehicles are sent to customers then inform their top managers about this issue through the main system. Then, managers give feedback to the authorized personnel to send vehicles to get customers' products through the SCM system.

6) inform_Cus

Before vehicles are sent, authorized personnel in the transportation firm inform customers about their products delivery time through e-mail or social media.

7) feedback_Trans

Customers give feedback to the authorized personnel in the transportation firm about their availability through e-mail or social media.

8) get_Product

Upon the demand from customers, authorized personnel in the transportation firm inform transportation staff through EDI and then vehicles set out to customer addresses for getting their return products. The phases of transportation are traced through vehicle tracking system. After getting customer products, staff use the 2-D bar-code system to recognize the products and send these information to company.

9) return_Back

After getting returned products from customers, vehicles with returned products get back to the transportation. This process is traced through vehicle tracking system.

10) repair_Process

When vehicles arrive the repair center , authorized personnel in the repair center use digital imaging to recognize the vehicles plate numbers for checking whether these vehicles belong to the authorized transportation firm then give permission them to enter repair center. Moreover, when the vehicles enter the retrieving area, RFID checks their entrance and send information to the main system. Then, staff brings down the products from vehicles and recognizes these products through 2D bar-code system upload this information into cloud service and place them at the shelves in the rooms of warehouse by giving entrance permission via speech system.

11) return_Back

After bringing breaking products at the repair center, vehicles go back to the transportation firm. This process is traced through vehicle tracking system.

12) inform_Firm

After the arrival of vehicles at the transportation firm, the authorized personnel in the transportation firm inform about the completion of transporting repairing products to the authorized personnel in the firm through the SCM system.

13) notrepair_Product

This process is shown to not repair products.

14) inform_Firm

After repair process cannot be completed, the authorized personnel in the repair center inform the authorized personnel in the firm to get new products from warehouse through the SCM system.

15) inform_Ware

Upon information from repair center, the authorized personnel in the firm inform the authorized personnel in warehouse to control new products which are new ones of repairing products in warehouse through the SCM system.

16) feedback_Firm

After getting information from firm, the authorized personnel in the warehouse inform the authorized personnel through the SCM system by finding new products in warehouse via cloud service.

17) inform_Trans

Upon information from warehouse, the authorized personnel in the firm inform the authorized personnel in the transportation firm about departure to warehouse to get new products through the SCM system.

18) trans_Process

Before departure starts, authorized personnel in the transportation firm check vehicles in the list in the main system which they created before and determine which vehicles are sent to warehouse then inform their top managers about this issue through the SCM system. Then, managers give feedback to the authorized personnel to send vehicles to get new products through the SCM system.

19) inform_Ware

Before vehicles are sent, authorized personnel in the transportation firm inform the authorized personnel in warehouse about the arrival of vehicles to warehouse through the SCM system.

20) go_to_Destination

The authorized personnel in the transportation firm order the transportation staff to set out through the main system and then vehicles set out and go to the warehouse and this transportation situation is traced through vehicle tracking system to check whether the vehicles are on the right way and then provide to arrive the warehouse by sending the road situations from the authorized personnel in the transportation firm.

21) ware_Process

When these vehicles arrive the warehouse, authorized personnel in the warehouse use digital imaging to recognize the vehicles plate numbers for checking whether these vehicles belong to the authorized transportation firm then give permission them to enter the warehouse. Moreover, when the vehicles enter the retrieving area, RFID checks their entrance and send information to the main system.

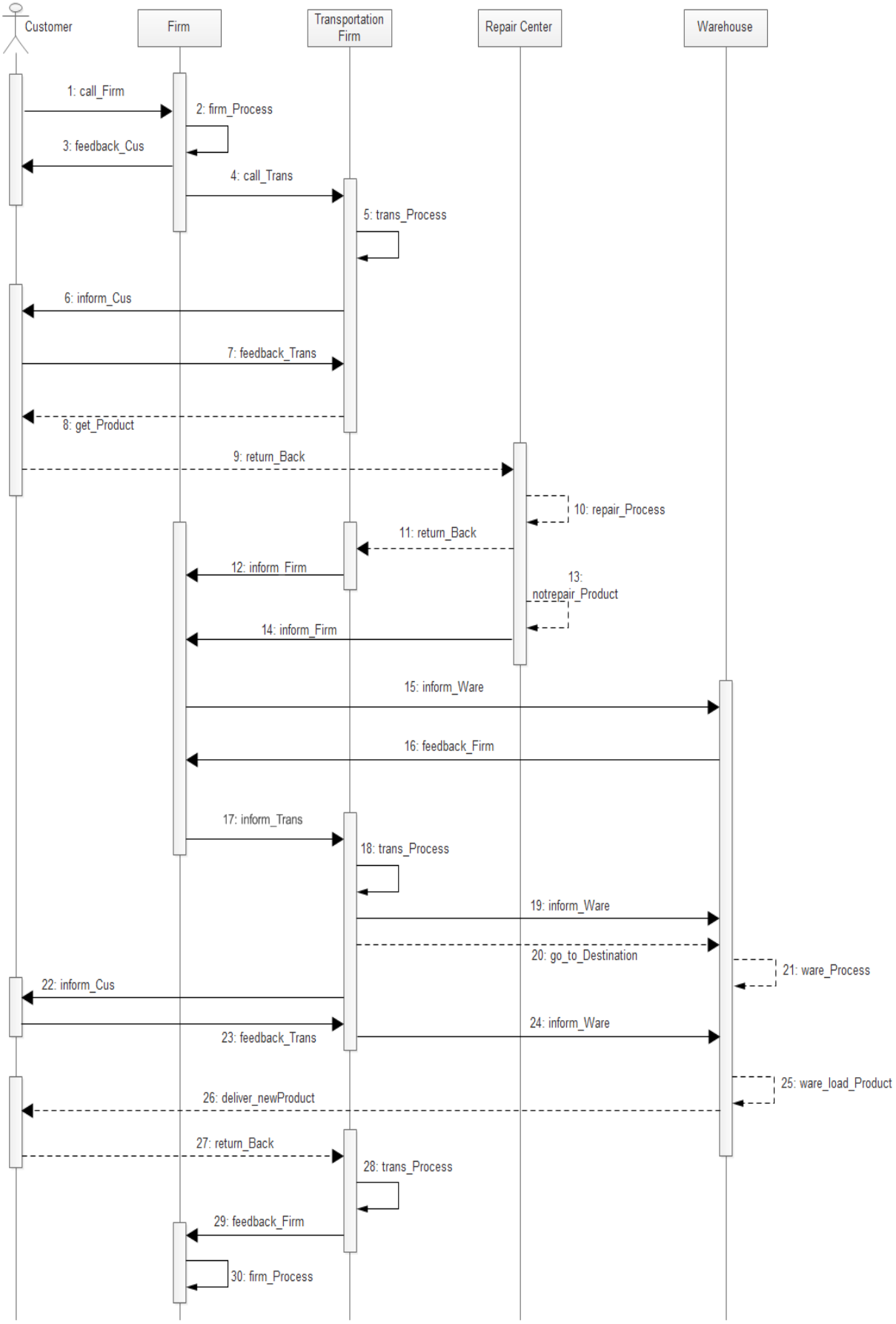


Figure 4.6: Non Repair Situation Return

22) inform_Cus

Because the authorized personnel in the transportation firms learn that the products are ready for delivery to customers, they send information to customers though e-mail or social media.

23) feedback_Trans

Upon information from transportation firms, customers give a feedback about time information of delivery to the authorized personnel in transportation firm though e-mail or social media.

24) inform_Ware

Upon information from customers, the authorized personnel in transportation firms give information about which products are delivered to customers on which day at which time to the authorized personnel in warehouse through the SCM system.

25) ware_load_Product

Upon information from transportation firms, the staff and workers in warehouse take products from shelves in different kinds of rooms by getting entrance permission via speech system and load them to vehicles. Moreover, products are read via 2D barcode to determine how many they are in vehicles.

26) deliver_newProduct

After loading process, vehicles go to the customers to deliver their new products through vehicle tracking system. When staff delivers new products to customers, they give information about the completion of delivery process through the SCM system.

27) return_Back

After staff in vehicles delivers new products to the customers, vehicles get back to the transportation firm. This process is traced through vehicle tracking system.

28) trans_Process

After the arrival of vehicles in the transportation firms, the authorized personnel in the transportation firm control vehicle conditions which are fuel capacity, arrival time from retrieving warehouse to transportation firm, damage conditions and range before going somewhere by the main system.

29) feedback_Firm

After vehicles return back transportation firm, the authorized personnel in the transportation firm inform the authorized personnel in the firm about the completion of the process through the SCM system.

30) firm_Process

After the process is completed, authorized personnel use ERP to enter accounting for register the cost of returning process check how this process takes via schedule.

CHAPTER 5

EMPIRICAL VALIDATION OF THE PROPOSED RSCM PROCESSES

In this chapter, the proposed model with 3 RSCM processes is compared to a company model for empirical validation to test whether it can be implemented in real life or not. At the same time, we have tried to understand time efficiency of each process in the model compared to related company's RSCM process.

5.1 About the Company

The company used for empirical validation was established in 1990's. Since then, it has been involved in activities related to RSCM. The company has focused on the recycling of household hardware and old products. In recent times, the company has also started to recycle plastic products in its work area, especially plastic water bottles, glasses and metal remains.

The company uses Microsoft Dynamics to manage its RSCM in real life. Although this program consists of different kinds of management modules used by different companies according to their work area, the company basically uses it for financial management, service management, manufacturing management, project accounting and reporting, supply chain management and warehouse management. For security, the company uses camera system, biometric fingerprint and door locker, In addition, the company uses RFID, VTS, CRM, e-mail server, 2D-Barcode which are the same ICT existing in the proposed model. Thanks to these technologies, it manages its RSCM processes among different entities such as customers, corporations, distributors and stores. In this way, products which may have different status are handled by company, and tracked and delivered to the destinations. In Microsoft Dynamics, financial management is used to provide transactions between the company and customers for refunding money. Service management is used for changing products' status from non-repaired to repaired before delivering them to the destination. Manufacturing management is used for demanding new products to replace old ones or non-

repairable products. Project accounting is used to determine available budget and cost of activities required for RSCM processes. Reporting is used to learn existing schedules in RSCM activities to determine possible repair date of a product and demand a new product. Supply Chain Management has many management functionalities, but especially inventory management and distribution management are related to company's RSCM activities. Inventory management is used to manage warehouse and collection area capacity efficiently. Distribution management is used to make plans for distribution of products which are repaired or replaced. Warehouse management is used to find new products in the stocks to replace out-of-date ones. Camera system is used to determine whether vehicles belong to the authorized transportation firm while they are entering warehouse, manufacturing and collection areas. RFID is used to identify vehicles while departing/arriving from/to warehouse, retrieving warehouse, collection area and repair center, and that information is sent to the program. Biometric fingerprint and door locker are used to give permission to staff in warehouse, collection area to take or put products from/to shelves. VTS enables company to monitor vehicles of transportation via GPS and make data communication between authorized individuals in the firm and drivers in the vehicles to give information about road situation via GPRS. CRM is used to manage the relationship between the company and customers. In this way, customers register to the CRM system of company and then login to the system using their e-mail addresses and password to fill the form about their complaints on their products. E-mail server is used to inform customers about delivering new products or repaired products, getting their returning products as well as informing top managers about RSCM activities from authorized personnel in the company. 2D Barcode is used to track the flow of products. Staff sends product information to the system before any activity by reading 2D barcode of the product.

5.2 Validation of the Proposed Model

When we compare the proposed model to the company's RSCM model, we observe a lot of similarities except some integrated systems or technologies such as social media technology, ERP, and digital imaging. For security, different technologies are used in these two models. While the proposed model is using speech recognition for security, the company is using fingerprint instead. The technology used by the company can by more effective, since fingerprint and door locker are more practical than speech recognition. Vehicle determination

is done using similar technologies, but with some differences. The proposed model determines vehicles through digital imaging (object recognition by image processing). However the company uses a camera system to determine them by help of security personnel. We think that the company had better use digital imaging instead of camera system because this technology can capture vehicles' plate number and appearance of vehicles, analyze them and recognize vehicles in a short time without getting help from personnel. On the other hand, although the proposed model is designed to run on a cloud platform, the company's system is designed and installed as an on-premise system. Both models have been designed with appropriate interfaces for employees to use system efficiently according to their jobs. Although there are different technologies in models, both of them perform the same RSCM processes.

In the company model, there are different kinds of return processes. However, we have worked on 3 RSCM processes in the proposed model. Therefore, only these three processes are compared to those of the company's processes. These are customer return, out of date product return, and repair and non-repair situation return.

5.2.1 Comparison of Customer Return Process

In customer return, there are some differences between two models. The customer return process of the proposed model (Figure 4.3) consists of the following main activities: getting back customers' products, refunding money, transportation from customer to retrieving warehouse, and transportation from warehouse to collection area. On the other hand, in the company model, customers' products are returned, money is refunded to them and these products are transported from customers to retrieving warehouse. They consider that transportation of products to the collection area should be another process because it is just activated when the capacity of retrieving warehouse is full or near to full. Therefore, the company' model just consists of first 15 steps in customer return of the proposed model (Figure 4.3). Another difference is that the company does not give feedback to customers after customer's forms in CRM are analyzed (Step 3 of Figure 4.3). They just informs customer about getting products (Step 6 of figure 4.3). In this way, the company completes the customer return process in 14 steps.

As a summary, there are two remarkable differences between two process models. First one is related to informing customers about their return applications. We evaluate that our model is more appropriate to increase customer satisfaction. Secondly, the activities numbered from 16 to 28 are considered as another process in the company model. For this part, the company model can be more appropriate for practical usage, since this part considers a bulk transportation for the products collected by many customer. However, our proposal can be more efficient for companies which want to track products separately.

5.2.2 Comparison of Out-of-date Return Process

In out-of-date product return, although many processes are similar in two models, there are a few differences between them. Firstly, the company does not give feedback to customer in step 3 and 15 of our model given in Figure 4.4. They just analyze forms filled by customers in CRM without giving feedback to them. Then, they start next activities to replace the out-of-date products. Secondly, their process does not include activities starting from 20 to the end of the process given in Figure 4.4. For the company, the important thing is just to retrieve out-of-date products from customer, bring them to retrieving warehouse and deliver new products to customers. It means that the company does not take into account the transportation process after putting these out-of-date products on retrieving warehouse. In this way, the company's process just consists of 19 steps of the model given in Figure 4.4.

Similar to the customer return process, there are two remarkable differences between two process models. First one is related to informing customers about their return applications. Second one is the transportation of collected products from retrieving warehouse to upper layers. Since the differences are very similar to the previous process, our evaluation given above for the customer return process is also valid for this process.

5.2.3 Comparison of Repair and Non-Repair Situation Return Process

In repair and non-repair situation returns, two models are mostly overlap with each other with some differences. Similar to previous process models, the company does not give feedback to customers in step 3, 7 and 21 of our model shown in Figure 4.5. They just analyze forms filled by customers in CRM, and inform customers about the product collection time

and delivery time. Furthermore, the process of the company does not include step 12, because they think that delivery of the product to repair center is not important. The critical activity is that the company should be informed by repair center about the result of repair activity. The company model does not also include from step 26 to the end of the process. They think that that part is under the responsibility of transportation firm. Therefore, the company's process just consists of 24 steps of the model given in figure 4.5.

When we compare the non-repair return process of the proposed model to the company's process model, we observe a similar situation with the repair return. The company does not give feedback to customers in step 3, 7 and 23 of our model given in Figure 4.6. Moreover, their model does not include step 12 and steps from 28 to the end of the process. The company's non-repair return process consists of 25 steps.

As a summary, two models have similar activities to achieve the aim of the process. However, there are also some differences. In our model, we try to inform customers when there is a development in the process and we evaluate that this can be better to increase customer satisfaction. On the other hand, we try to track the activities of products in a detailed manner. Therefore, we evaluate that our proposed model can improve the companies process.

CHAPTER 6

CONCLUSIONS

Developing technology attracts many researchers to propose different kinds of studies related to SCM to increase product qualities, develop new technological work models and produce products in shorter time. These studies generally cover production, transportation and deployment activities with the usage of Information and Communication Technologies (ICT) in SCM. However, these studies are generally focused on the forward processes of SCM. There are only a few studies investigating reverse SCM. Moreover, ICT are not examined in detail by those studies. In this thesis, a new approach has been proposed to troubleshoot this issue. This new approach covers a SCM system with reverse supply chain management processes. We have especially focused on ICT usage in RSCM. To make the model clearer, three RSCM processes are modeled using the sequence diagram of UML to trace the steps. Moreover, ICT usage on these steps is explored in detail.

In more detail, in this thesis, SCM and RSCM with their processes are explained in Chapter 2 as background information for the proposed model. The research about ICT usage in SCM is explained in Chapter 3. The objective of this chapter is to introduce information and communication technologies used in the proposed model. In this way, the model is explained and illustrated briefly with flows among entities step by step. The proposed model is explained in detail in Chapter 4. First, a general overview of the system is given and then selected RSCM processes are modeled using sequence diagrams and explanations. In Chapter 5, empirical validation of the proposed model is done by comparing the proposed model with the implemented model of a company to determine whether it can be implemented in real life.

With sequence diagrams, RSCM activities can be traced visually in an easy way. This increases understandability of the model. Therefore, interested readers can trace RSCM activities step-by-step and read related explanation about each activity to understand the activity and also ICT usage for that activity.

Comparing a proposed model to an implemented model of the company has been done with experimental validation because this proposed model wants to be shown to determine

whether it is applicable in a real life. Furthermore, the proposed model is discussed with company's model regarding which kinds of ICT according to existing or no existing ICT in each model, which model is more logical to use in real life and which favorable and unfavorable aspects of each model are with respect to time duration.

RSCM is essential for companies to sustain their customers' satisfaction and business environment because customers have to take it into account to getter better service from them that they buy products. Companies have to improve RSCM with efficient usage of information technologies because companies quickly want to response to customer about their return issues and solve their return issues as early as possible. Therefore, this study is important to alleviate the lack of studies in this field and may help to them having intension to improve their RSCM. The proposed model can be extended with the following improvements in order to have a better model as the future work this study:

- The model is developed as paperwork and it should be implemented and tested in real life.
- The usage of some information and communication technologies in the proposed model is explained. However, other technologies can be investigated to improve the proposed model.
- We have investigated just three RSCM processes. Therefore, other RSCM processes can be examined.
- The proposed model is compared with a single company's model. Therefore, it can be validated comparing with other companies' models to produce exact results about RSCM processes.
- Since we have used cloud technology in a limited way in the proposed model, cloud technology can be investigated in more detail for RSCM.

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