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Thesis topic:

Opportunities of Blockchain technologies in closed-loop supply chain management

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Abstract

During recent decades, closed-loop supply chain which is composed of forward and reverse supply chain flows has gain more attention among global society due to initial reasons such as: environmental concerns about after-use effect of products, competitiveness and reputation of companies to higher position in eyes of consumers, profitability by reusing the products through reverse cycle flow, legislation policies imposed by governments, and scarcity of natural resources. However, by growing up supply chain networks and complexity, there are some challenges and problems which is needed to be considered. Information-related problems and transparency issues not just about the product but also about the different layers of supply chain parties are big controversial issues in the supply chain especially in backward/reverse supply chain. Therefore, for managing effectively forward and reverse flows, we need comprehensive, symmetric, and reliable information about the product through its life cycle, the engaged supplier, transparency and visibility among the whole supply network. Beside this, counterfeiting, grey markets, and safety in the whole product network are another problems to be considered. Consequently, to eliminate the mentioned problems, Information and communication technologies play a vital role in the whole supply chains. Among current available information technologies, blockchain and RFID technologies are the most relevant emerged technologies which have a great potentiality to solve the discussed problems in the whole supply chains to bring symmetric, trusted, and transparent information in the chain and increase product traceability, information sharing and planning.

In this study, we firstly highlighted the current problems and challenges in closed-loop supply chain in order to prove the need and applicability of blockchain in this area. Then, by using a top-down approach, after discussing about the forward and reverse flows in closed-loop supply chains, the role of information and communication technology in reverse logistics and available technologies to support supply chains are considered. After that, a model/platform is proposed based on blockchain and RFID technology in order to solve information related problems in the closed-loop supply chain. And showed how this decentralized platform can guarantee the efficiency of the network and increase trust and transparency among actors in the chain. In addition, how to adopt it in reverse logistics. Furthermore, we made an example about how to implement the proposed system. Finally, advantages and disadvantages of such system and challenges issues are pointed out.

Keywords: closed-loop supply chain management, forward logistics, reverse logistics, information technology, blockchain technology, RFID technology, transparency, counterfeiting, smart contracts, trust, traceability, decentralization.

Executive summary

Nowadays, due to growing of supply chain networks in one side and in another side, due to globalization approach and diversification trends in manufacturing and products, goods in order to be produced and reach to end consumers in forward supply chains have to pass from different suppliers, and distributers while, there is yet inadequate information about how, when, where, the products are produced, processed, manufactured, transferred, and used through their life cycle. Beside this, in reverse supply chain, a very serious problem is the lack of information and information systems to know about previous product journey in its life cycle. Therefore, in order to make the best decision about the right reverse logistics operations on returned products, efficient information systems is required for individually tracing and tracking the returns of the products and consequently linking with the previous sales. Another challenge in backward flow of closed-loop supply chain which is needed to be addressed is the quality of returned product which case by case is different. While, in forward flows the quality is uniform. By having enough information about the whole product life-cycle, its destinations geographically, consumers and product detailed information, manufacturers and engaged actors, making better decision is achievable based on the right and current quality level and status of the product. Secondly, many supply networks and costumers are suffering from lack of transparency and visibility which leads to demand growing for more accurate information about the products origins, and the owned tiers of supplier. Some negative consequences of supply chain invisibility are: Foxconn suicide scandal in 2010 because of imposing difficult work conditions and Nike child labor scandal in 1996 due to employing underage children in Asia. Without transparent information product traceability is difficult. End to end supply chain transparency can help to build the product flow from raw material, to manufacturers, distributers, certifiers, and so on. Lack of transparency and traceability in supply chains will causes safety, risk, and fraud issues. Thirdly, Current supply chains rely heavily on centralized information management systems, which are within organizations. For example, enterprise resources planning systems (ERP). And, storing data in one entity in the whole supply chain will increase the vulnerability of the total network because the sensitive information is just in one single organization and in case of occurring failure in the organization, a lot of damages will reveals in the whole supply chain network. In addition, centralized information system will may leads to trust issues among other actors or may in case of trust, we cannot guarantee the credibility, and accuracy of information because there is a great potentiality to misuse the data. Therefore, Information sharing which is a prerequisite for effective collaboration among actors is very important to succeed in both forward supply chain and reverse supply chain. Fourthly, another problem in current closed-loop supply chains which I am going to address and improve in my thesis is collaboration among different parties in the supply network. By improving collaboration, the relationship and trust between actors would be stronger and also leads to reducing costs and risks. To reach this aim, the best way is using smart contracts. Contracts bind actors to each other's by determining the conditions of transaction to execute the set terms such as payment terms and timing. Although, ensuring contract fulfilment is yet a concern because of information asymmetric in supply networks.

The main objective of this research study is trying to guarantee accuracy, credibility, and transparency of information and processes mainly related to reverse logistics from a closed loop supply chain management perspective and proposing a model/platform to integrate forward flow of supply chains with the reverse flows in order to benefit from appropriate stored data related to product journey and suppliers to fight against moral scandal and invisibility of suppliers in one side and transparency of the whole closed-loop supply chain in another side. Regarding to this aim, we will try to establish a new decentralized information system based on blockchain technology and RFID. Relying on this information technologies we are able to solve the information-related problems, trust issues and opacity in closed loop supply chains. Subsequently, In order to achieve my research purpose, I am going to address and discuss my research questions in my thesis which are knowing how to integrate forward/direct supply flows with reverse/backward supply flows and how to enable blockchain technology with RFID in closed-loop supply chain networks for building new decentralized informatics & traceability system and also how this new traceability system work in the whole supply chain in order to increases efficiency on information flows? Then, what are the advantages & disadvantages of using blockchain technology with RFID in building a closed-loop supply chain/reverse logistics system? And finally, what are the necessary requirements to implement such systems in closed-loop supply chains?

So far many studies have been done by scholars about the usability of blockchain technologies in different sectors. Among them, the majority of them is in financial sectors while few studies have been done in supply chain networks. In financial sectors the initial study has been done by Satoshi Nakamoto in 2008 [1] about bitcoin as a digital currency and a Peer-to-Peer Electronic Cash System, which doesn't need any intermediaries like central authority or banks to transfer money from one person to other person. In supply chain networks approximately all studies and researches is done mainly for forward flow of supply chains. Moritz Petersen, et al. (2018) [2] showed the potentiality and opportunities of Blockchain in Supply Chain and Logistics and how these sectors can benefit from it. However, like another new technologies, blockchain has many barriers to overcome in SCM. Sara Saberi, et al. (2018) [3] demonstrated the relationship between blockchain technology and sustainable supply chain management. In their studies they introduced four barriers to adopt properly blockchain technology in SCM. These barriers are: inter-organizational, intra-organizational, technical, and external barriers. The main question which has been explored recently is about how blockchain functions within the context of the supply chain. Unlike Bitcoin and other digital currencies in financial blockchain platform, blockchain-based supply chain networks may require a closed, private, permissioned blockchain with multiple, and limited players. Therefore, privacy and confidentiality level, beside the limited number of permitted actor, is one of the initial decisions yet. Based on this, Abeyratne and Monfared. (2016) [4] proposed a decentralized blockchain- based platform by using distributed ledger in manufacturing supply chain. To clarify their model, he used manufacturing of cardboard boxes as an example. Their proposed platform was mainly focused on direct supply chain. Furthermore, Blockchain reliability and transparency are another benefits which helps companies to facilitate material and information flow through the supply chain. Tian. (2016) [5]by introducing a blockchain & RFID system together showed how companies and their customers for agri-food supply chains can benefit from this traceability system to increase the level of trust and fighting against counterfeiting issues. In addition, based on the concept of smart contracts in blockchain which is programmed regarding “if conditions”, Tian. (2017) [6]proposed the use of blockchain and internet of things (IOT) technology to increase the automation level of control and increasing safety and quality of agri-food products. As it was already mentioned in above sentences, there are too few researches focusing on enabling blockchain & RFID technology in reverse supply chains beside forward supply chain. Among them, they paid less attention to a comprehensive reverse logistics operations and just considered recycling operations. For example, Abeyratne, S.A. and monfared, R.P. [7] Proposed a model based on blockchain applying in supply chain networks. They considered mostly forward flow and in backward flow they just took into account recycling operation and relatively the required data to be embedded in tags and distributed ledger was only related to direct flows. While, to adopt the model in closed-loop supply chain, integration between these 2 flows are required. Therefore, to integrate them, there are other specific operations in RL such as repairing, recovering, and remanufacturing that should be taken into consideration. Another study was done by Tian [8]in which they suggested an effective traceability system in order to increase safety of agri-food supply chains by applying blockchain and RFID and only they focused on forward flows. In this research, a decentralized information system is developed based on RFID and blockchain technologies for closed-loop supply chain monitoring and traceability. Compare to the centralized systems, this new system provides an information platform for all the supply chain members including not just forward supply chain flows but also reverse supply chain information flows with openness, transparency, neutrality, reliability and security.

In my studies to reach the purpose and answer the research questions, first of all I used different research resources and materials such as different academic journals, companies' websites, Google Scholar, and Youtube channels in order to increase my knowledge about the topic. During this phase I used different relevant keywords and their combinations to enhance my insight which are: supply chain management, forward logistics, reverse logistics, RFID, blockchain technology, block chain, smart contracts, transparency, counterfeiting, information technology, decentralization, confidentiality, traceability, and closed-loop supply chain. In addition, during the selection of relevant research studies, the purpose of the thesis, research gaps, and research questions were taken into consideration. It should be noted that due to the fact that just few companies so far in the world have utilized blockchain technology in their supply chain networks and mostly they are working on pilot projects to examine and test the results. So, no real data is available to be considered for improving the quality of this research. Consequently, based on my researches and after deeply understanding of the issue in direct logistics cycle, I am going to extend the usability of the combination of blockchain and RFID technology together in reverse logistics also. Then, discussing the prerequisite conditions, required data coming from forward logistics, and new data which must be embedded in product profile to make it integrated for the whole supply chain. After that, by mentioning 2 different scenarios based on the type of reverse logistics operations for returns I conduct the development of the model. And finally the advantages and disadvantages of such system is demonstrated.

By implementing proposed model in closed-loop supply chains we would benefit from Fighting against counterfeiting and grey markets, Competitive advantages, Improvement of supply chain planning and reaction time, Increasing credibility and trust, tracking and traceability. However, as any other emerging technologies in their first ages, there are still some disadvantages such as high cost of utilization especially RFID tags and also the size of the blocks in Blockchain. Initially, every time the transaction is done during our closed-loop supply chain model, the size of the database will grow. It will causes the storage problems for the blocks. Subsequently, every node has to maintain the chain to run, the computing requirements (e.g. needed time to accomplish the transaction) increase with each use. By all and all, further studies is necessary about the appropriate cost evaluation of adopting such system in closed-loop supply chain, improving, and investigating the model effectively. In addition, Investigations are needed to evaluate more effectively the case studies and pilot programmes and provide valuable practical information to improve blockchain implementation. Post-implementation success and failure indicators of such technology can also be addressed in the future research. Finally, Understanding the full implications of blockchain technology with RFID in the closed-loop supply chain will require more efforts (noting that no study is done so far about adaptation of blockchain technology and RFID with closed-loop supply chain perspective in order to focus more and precisely on reverse logistic flows).

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Introduction

From the past few years, closed-loop supply chains which is composed of forward and reverse supply chain (e.g. Forward supply chain flows starts from upstream flow and ended to final customers and includes activities such as acquiring the raw material from suppliers, producing the product and deliver it to end consumers by distributers. While, in reverse supply chain flows the starting point mainly is from end consumers and ended to manufacturers, supplier, and/or distributors by adding additional activities like collection of returns from customers, repairing, recovering, recycling, and reprocessing of used products) has gain more attention between scholars and societies due to environmental, economical, ethical, and social concerns about products and also suppliers [9]. In addition, to review the consumed products in the environment, even in some countries, laws have been introduced to collect consumed products by their manufacturing companies. On the other hand, reverse logistics benefit companies in acquiring financial value through the second-hand products or parts, or through recycled materials. Relatively, the need for accurate information and transparency in supply chains is addressed. Furthermore, due to information-related problems some kind of scandals has happened such as horsemeat scandal of European supermarkets in 2013 [10], the 2015 E. coli outbreak in Chipotle Mexican Grill outlets which made customers ill [11] and consequently led to a significant drop in its stock prices up to 42%, and Foxconn suicide scandal in 2010 [12]. This kind of events has made people lose their trust on markets. Consequently, an efficient and reliable supply chain system which ensures bringing a quality product to consumer is only way to rebuild the trust of public on such markets. With rapid growth of internet, a lot of advance technologies have been implemented in supply chain management system to trace the flow of products journey between the intermediaries in supply chain networks. But all these technologies are centralized and controlled by a central authority which is monopolistic and asymmetric. Therefore, leading to trust problems such as tampering, corruption and fraud. Consequently, adapting blockchain and RFID technology as an innovative technologies in our traditional closed-loop supply chain system is the key to address all the problems in the area.

For more details, blockchain and RFID[1] in terms of technology and services is used to improve the trade in products and components, including marketing, buying, selling, planning and controlling, visibility, traceability, and reliability. blockchain technology protect data by sharing business information, maintaining business relationships, conducting business negotiations, and on the other hand, RFID helps companies to fight against counterfeiting and grey market by unique radio frequency tags. Therefore, these technologies lead to increasing efficiency, controlling, and facilitating commercial transactions.

In order to create a systematic vision, we divide the contents of this article into chapters. In the first chapter, we reviewed the literature and the work carried out in the field of study, research

[1] Radio frequency identification

gaps, problem statements in closed-loop supply chains, and study questions. In the second chapter, considering the importance of the supply chain, introducing the general review of different SCM[2] aspects. In the third chapter we presented the forward logistics which is one of the important processes of the closed-loop supply chain. In the fourth chapter, is expressed the reverse logistics, the activities and important topics related to it. In the fifth chapter, we demonstrated the IT technologies adoptable in reverse logistics. In sixth chapter, we mentioned new technologies including RFID and blockchain which are useful in improving reverse flows. Finally, in the seventh chapter we proposed our suggestions, analysis and result. We hope this article be useful for all, and improve the knowledge about reverse logistics and applicable IT[3] technologies in the whole sustainable supply chain.

[2] Supply chain management
[3] Information technology

1 Research study

1.1 Literature review

1.1.1 Supply chain management and forward logistics

In the supply chain management area there are a lot of research studies available which focus on different issues in SCM. John T. Mentzer et al (2001) [13] presented in his studies various definitions of some terms such as supply chain, supply chain orientation, and supply chain management. He defines the supply chain "*as a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer"*. In addition, supply chain management is defined by him "*as the recognition by an organization of the systemic, strategic implications of the tactical activities involved in managing the various flows in a supply chain"*. Finally, he mention that supply chain management is "*the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole*". Veera Boonjing et al. (2015) [14] did a research to understand the impact of supply chain management components on firm performance through a questionnaire survey, Correlations and simple regression analysis and finally found that there is a positive relationship between components and performance and also among all components of supply chain management, 5 of them should be more considered by firms which are Planning and Control, Workflow Structure, Product Flow Facility Structure, Management Methods, and Knowledge Management, respectively. However, the existence of risk and uncertainty in any subject is undeniable especially in supply chain management and logistics in order to make better decisions. For this purpose, Joseph L. Cavinato (2015) [15] have investigated in this issue by considering five major risk aspects which are physical, financial, informational, relational, and innovational. Furthermore, by applying Kraljic matrix they have addressed the importance of these 5 categories and necessity of calling supply chain governance.

1.1.2 Reverse logistics

So far many studies have been done in reverse logistics area for covering different aspects of reverse logistics. Some have investigated in the fundamental concept of reverse logistics and definitions. For instance, Genchev. (2009) [16] examined the relocation of returns to the wholesale computer company (WCC), as well as a description on implementing a successful reverse logistics program in companies. B.C.J. Zoeteman et al. (2010) [17] addressed the need and potential of products Recycling methods in a high quality and presented the quantitative estimates of current and future electric wastes between regions of the world that produce and process waste. Beside, some studies have been focused on theory studies and quantitative methods in revers logistics. For example, Listes, R et al. (2005) [18] provided a stochastic integer programming model with the aim of maximizing profit by considering the uncertainty in demand, as well as the type and quality of returned products in a stone recycling network, and expanded this model For several modes and with different scenarios. V. Ravi et al. (2005) [19] showed a decision-making model based on an analytic network process (ANP). F. Schultmann et al. (2006) [20] provided a modeling reverse logistic tasks within closed-loop supply chains, which used Tabu search (TS) algorithm to solve it. Ko H.J., et al (2007) [21] presented a genetic algoritm-based heuristic for the dynamic integrated forward/ reverse logistics network for third-party providers (3PLs). In this model, they have used warehousing and transportation operations as key operations in the third-party vendor market. H. Min, et al. (2008) [22] showed a dynamic design of a reverse logistics network from the perspective of third-party logistics service providers. They used a combination of warehouse and repair facilities in their integrated network, instead of using separate warehouses and collection facilities. Furthermore, some studies have been investigated in applicable designing for specific RL[4] cases. In Table 1-1 they are demonstrated.

Table 1-1: case studies in RL

Article	Applicable designing	Country
AI. Barros, et al (1998) [23]	A two-level network for recycling sand	Netherland
M.Fleischmann, et al (2001) [24]	Copier machine remanufacturing	Europe
O. Listes, et al (2005) [25]	Recycling sand from disposal wastes	Netherland
F. Schultmann, et al (2006) [26]	Used vehicles transportation	Germany
I.L. Blanc, et al (2006) [27]	Collecting containers from used vehicles disassemblers	Netherland
M.A. Seitz, et al (2007) [28]	engine remanufacturing	Europe
R.K. Pati, et al (2008) [29]	Paper recycling	India
R. Geyer, et al (2010) [30]	cell phone reuse and recycling	U.S
P. Sasikumar, et al (2010) [31]	truck tire remanufacturing	India

[4] Reverse logistics

1.1.3 Information technology in reverse logistics/closed-loop supply chain

Recently, Information technology (IT) has become a must-be in reverse logistics supply chains in order to improve the information sharing, communication between partner, and efficiency. Vaidyanathan Jayaraman, et al. (2008) [32] has shown the necessity of using IT in reverse supply chains. They have introduced the problems related to returns flows and the importance of utilizing new emerging technologies such as radio frequency identifications (RFID) and also improving in ERP systems to collaborate better between parties both in forward flows and reverse flows. In addition, they mentioned that e-marketplaces have a great potential to adopt the information technologies. Patricia J. Daugherty, et al. (2002) [33] have discussed firstly about the information systems (IS) advantages such as supporting capability, compatibility, and technologies in their studies and, on the other side, introduced operating/financial performance evaluation in RL. Then, by adopting these 2 subject, they analyzed the relationship commitment by utilizing quantitative methods. Consequently, besides applying sophisticated IS support to maintain satisfaction levels across the supply chain, a commitment to the reverse logistics relationship is essential to overall program performance. V. Ravi, et al (2005) [34] analyzed the interactions among the barriers of reverse logistics. They mentioned that Lack of information and technological systems is a very serious barriers in reverse logistics. They adopted the Interpretive Structural Modeling (ISM) methodology to understand the mutual influences among the barriers so that those driving barriers, which can aggravate few more barriers and those independent barriers, which are most influenced by driving barriers were identified. Festus O, et al (2010) [35] investigate on how the use of information technology and supply chain management initiatives (information sharing and collaboration) impact a company's performance in reverse logistics. And in their studies they showed that investment in IT alone cannot improve a company's performance; managers should take full account of IT attributes when deciding IT in RL.

1.1.4 RFID technology in reverse logistics

Ka¨rkka¨inen and Holmstro¨m, (2002) [36] defined RFID as a wireless technology, which allows transmission of information without the physical connection or line of sight that is required by optical technologies such as bar codes. C.K.M. Lee. (2009) [37] proposed the RFID-based reverse logistics framework and optimization of locations of collection points which allow economically and ecologically reasonable recycling. Juan Jose Nativi, et al. (2012) [38] analyzed the effect of RFID adoption on a decentralized supply chain with reverse logistics operations. They used regression and sensitivity analyses to measure cost performance by mainly relying on demands, returns, and collection lead-times. Obviously, RFID technology has many benefits for companies. Araujo, et al. (2015) [39] studied on Cost Assessment and Benefits of using RFID in Reverse Logistics by focusing on electronics waste.

1.1.5 Blockchain technology in supply chain management and reverse logistics

Blockchain has received significant attention globally. The first evidence of this new technology happened in finantial sector by Bitcoin. Satoshi Nakamoto (2008) [1] has created Bitcoin, a digital currency and as a Peer-to-Peer Electronic Cash System, which doesn't need any intermediaries like central authority or banks to transfer money from one person to other person. Wei-Tek Tsai, et al. (2016) [40] presented in his studies system-related issues such as performance, security, performance and scalability for blockchain in financial applications and showed how this system which was built on Blockchain platform could challenge the existing financial systems and eliminate the problems related to scalability and privacy and etc. Moritz Petersen, et al. (2018) [2] showed the potentiality and opportunities of Blockchain in Supply Chain and Logistics and how these sectors can benefit from it. However, like another new technologies, blockchain has many barriers to overcome in SCM. Sara Saberi, et al. (2018) [3] demonstrated the relationship between blockchain technology and sustainable supply chain management. In their studies they introduced four barriers to adopt properly blockchain technology in SCM. These barriers are: inter-organizational, intra-organizational, technical, and external barriers. The main question which has been explored recently is about how blockchain functions within the context of the supply chain. Unlike Bitcoin and other digital currencies in finanatial blockchain platform, blockchain-based supply chain networks may require a closed, private, permissioned blockchain with multiple, and limited players. Therefore, privacy and confidentiality level, beside the limited number of permitted actor, is one of the initial decisions yet. Based on this, Abeyratne and Monfared. (2016) [4] proposed a decentralized blockchain- based platform by using distributed ledger in manufacturing supply chain. To clarify their model, he used manufacturing of cardboard boxes as an example. Their proposed platform was mainly focused on direct supply chain. Furthermore, Blockchain reliability and transparency are another benefits which helps companies to facilitate material and information flow through the supply chain. Tian. (2016) [5]by introducing a blockchain & RFID system together showed how companies and their customers for agri-food supply chains can benefit from this traceability system to increase the level of trust and fighting against counterfeiting issues. In addition, based on the concept of smart contracts in blockchain which is programmed regarding if conditions, Tian. (2017) [6]proposed the use of blockchain and internet of things (IOT) technology to increase the automation level of control and increasing safety and quality of agri-food products.

1.2 Research gap in the current literature

Regarding studies done, there are few researches focusing on enabling blockchain & RFID technology in reverse supply chains beside forward supply chain. Among them, they paid less attention to a comprehensive reverse logistics operations and just considered recycling operations. For example, Abeyratne, S.A. and monfared, R.P. [7] Proposed a model based on blockchain applying in supply chain networks. They considered mostly forward flow and in backward flow they just took into account recycling operation and relatively the required data to be embedded in tags and distributed ledger was only related to direct flows. While, to adopt the model in closed-loop supply chain, integration between these 2 flows are required. Therefore, to integrate them, there are other specific operations in RL such as repairing, recovering, and remanufacturing that should be taken into consideration. Another study was done by Tian [8]in which they suggested an effective traceability system in order to increase safety of agri-food supply chains by applying blockchain and RFID and only they focused on forward flows. In this research, a decentralized information system is developed based on RFID and blockchain technologies for closed-loop supply chain monitoring and traceability. Compare to the centralized systems, this new system provides an information platform for all the supply chain members including not just forward supply chain flows but also reverse supply chain information flows with openness, transparency, neutrality, reliability and security. We believe that such system significantly enhance product traceability, planning and management, and trust through the whole supply chain.

1.3 Problem statement & relevance

In reality, millions of products are manufactured every day through the word. In comparison with the past decades, supply chain networks have become more and more complicated and complex in one side. And in another side, due to globalization approach and diversification trends in manufacturing and products, the number of actors has increased [41]. Therefore, goods in order to be produced and reaching to end consumers in forward supply chain pass from different suppliers, and distributers. However, there is inadequate information about how, when, where, the products are produced, processed, manufactured, transferred, and used through their life cycle. Yet, in many cases this product journey remain as invisible dimension [42]. In reverse supply chain, a very serious problem is the lack of information and information systems [43]. Undoubtedly, excellent information system can be very beneficial to effectively support reverse logistics operation decisions, selection procedure, and to develop linkages among them [44]. Furthermore, another problem is lack of knowledge about product journey and linkages to previous operations and sales in reverse supply chains. So, in order to make the best decision about the right reverse logistics operations on returned products, efficient information systems is required for individually tracing and tracking the returns of the products and consequently linking with the previous sales [45] [46]. Another challenge in backward flow of closed-loop supply chain which is needed to be addressed is the quality of returned product which case by case is different. While, in forward flows the quality is uniform [47]. By having enough information about the whole product life-cycle, its destinations geographically, consumers and product detailed information, manufacturers and engaged actors, making better decision is achievable based on the right and current quality level and status of the product.

Beside lack of efficient information in closed-loop supply chain, Transparency which is defined as a disclosure and transference of high level information along the whole supply chain is one of the most important issues in supply networks which has increased global attention recently [48] [49] [50]. So, many supply networks and costumers are suffering from lack of transparency and visibility which leads to demand growing for more accurate information about the products origins, and the owned tiers of supplier [51] [52] [53]. Some negative consequences of supply chain invisibility are: Foxconn suicide scandal in 2010 because of imposing difficult work conditions and Nike child labor scandal in 1996 due to employing underage children in Asia [12] [54]. Without transparent information product traceability is difficult. End to end supply chain transparency can help to build the product flow from raw material, to manufacturers, distributers, certifiers, and so on [55]. Lack of transparency and traceability in supply chains will causes safety, risk, and fraud issues. Some examples are horse meat scandal in Europe [10] and E. coli outbreak within Chipotle Mexican Grill outlets which caused many peoples ill [11].

Current supply chains rely heavily on centralized information management systems, which are within organizations. For example, enterprise resources planning systems (ERP) [56]. And, storing data in one entity in the whole supply chain will increase the vulnerability of the total network because the sensitive information is just in one single organization and in case of occurring failure in the organization, a lot of damages will reveals in the whole supply chain network [57]. In addition, centralized information system will may leads to trust issues among other actors or may in case of trust, we cannot guarantee the credibility, and accuracy of information because there is a great potentiality to misuse the data [58]. One example of abusing the trust and lack of accuracy is VW emissions scandal in 2015 due to faked diesel test [59].Therefore, decentralization which means sharing information between engaged entities in the supply chain networks will improve to solve problems regarding centralization. Information sharing which is a prerequisite for effective collaboration among actors is very important to succeed in both forward supply chain and reverse supply chain [60] [61].

Another issue in closed-loop supply chains which needs to be considered among actors is coordination of transactions which can improve the relationship and trust between actors and reduces costs and risks. To reach this aim, the best way is using the contract [62]. Contracts bind actors to each other's by determining the conditions of transaction to execute the set terms such as payment terms and timing [63].although, ensuring contract fulfilment is yet a concern because of information asymmetric in supply networks [64]. In terms of international financial transaction, assume that one party of supply chain is in Europe zone with EUR currency and another party is in US zone with dollar currency. If one of them want to pay money to another one through current, traditional payment system firstly that party should make a request to his bank in order to pay the money to other party. Then, the bank should have a correspondent bank (e.g. a bank which is co-partner of my bank and so fully trusted relationship is available among them) to make the request for paying money to target party. After that, the correspondent bank make a settlement with the central bank of his country to pay the fee in that party. As it is obvious, such payment system in order to pay a single transaction needs multiple intermediaries and is time-consuming, complex, and consequently causes higher costs [65].

To summarize this section, in order to have a systematic view about above sentences, we have depicted the current problems in closed-loop supply chain networks with the relevant causes, consequences, and effects in Figure 1-1 .

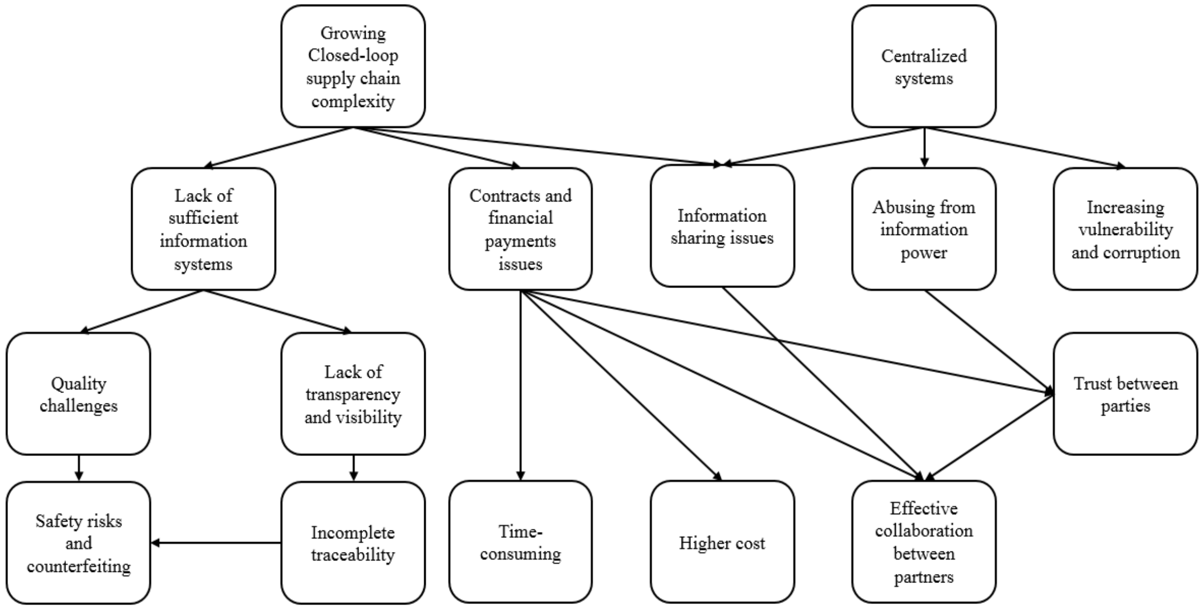

Figure 1-1: current problems in CLSCs with relevant causes and consequences

1.4 Research questions and aim

As we introduced already in section (1-3), the main goal of this research study is trying to guarantee accuracy, credibility, and transparency of information and processes mainly related to reverse logistics from a closed loop supply chain management perspective. Regarding to this aim and literature gap as we mentioned in section (1-2), we will try to establish a new decentralized information system based on blockchain technology and RFID. Relying on this information system we are able to solve the information-related problems, trust issues and opacity in closed loop supply chains. Subsequently, In order to achieve our research purpose, we propose the following research questions which are:

1. How to enable blockchain technology in a closed-loop supply chain system?

2. How to implement blockchain and RFID technologies together for building new decentralized informatics & traceability system in reverse logistics?

3. How does this new traceability system work in the whole supply chain and increases efficiency on information flows?

4. What are the advantages & disadvantages of using RFID & blockchain technology in building a closed-loop supply chain/reverse logistics system?

5. What are the necessary requirements to enable this system (RFID and blockchain technology combination system) in reverse logistics processes?

2 Theoretical framework

2.1 Supply chain management overview

2.1.1 An Introduction to Supply Chain Management

Nowadays, with increasing complexity in the production process and the number of competitors on the world scale, traditional methods are not efficient and with the development of global competition, products should be available to the customer at a proper time and place. Hence, customer satisfaction is one of the issues that has been emphasized more and more, and with increasing diversity in products, customers are demanding higher quality of products and services before and after sales by producers. therefore, due to increasing in global competition and customer demand for higher and quicker services has made organizations no longer be able to handle all the work alone, and regarding this, they need resources and components out of the organization in order to avoid wasting a lot of money and time and then proceeding toward integration and coordination of all operations and activities related to the organization.

Supply chain management is a phenomenon which helps us to provide more reliable customer services with higher quality, and lower cost. In this chapter, we try to have an overview of supply chain and its concepts.

2.1.2 Supply Chain Management History

In decades of the 1960s and 1970s, organizations were trying to increase their competitive ability to produce products with better quality at lower costs by standardizing and improving their in-house processes. At that time, the prevailing thought was that engineering and design, as well as coherent production operations, would be the prerequisite for achieving market demands and, consequently, gaining more market share. For this reason, organizations were doing their best to increase efficiency. In the 1980s, with the increasing diversity in the expected patterns of customers, organizations were increasingly interested in increasing the flexibility of product lines and developing new products to meet the needs of customers. In the 1990s, along with improvements in the production processes and the use of reengineering patterns, many industry managers found that for market continuation only improvement of internal processes and flexibility in the company's capabilities was not enough, but suppliers of components and materials should also Produce the best quality and lowest cost, and distributors of products should also be in close proximity to market development policies. With such an attitude, the approaches to the supply chain and its management revealed. On the other hand, with the rapid development of information technology in recent years and its widespread use in supply chain management, many key chain management activities are under way with new methods.

2.1.3 Definition of Supply Chain Management

The concise and comprehensive definitions that can be drawn from the supply chain and supply chain management are:

Supply Chain: The supply chain is included in all activities related to the flow and conversion of goods from the raw material stage (extraction) to delivery to the final consumer, as well as related information flows. In general, the supply chain is a chain that involves all activities related to the flow of goods and the conversion of materials from the stage of preparation of the raw material to the final delivery of the finished product to the consumer. Beside the flow of goods, there are two other flows, which are flow of information, and flow of funds and credits.

Supply Chain Management: Supply chain management include the integration of supply chain activities as well as their related information flows by improving chain relationships to achieve a reliable competitive advantage. Therefore, supply chain management is the process of integrating supply chain activities as well as related information flows by improving and coordinating activities in supply chain. So, in order to examine a unique organization within the framework of these definitions, both distribution channels and providing networks should be considered. The definition for supply chain, contain the issues of information system management, inventory and procurement, production scheduling, order processing, inventory management, warehousing and customer service. In order to effectively manage the supply chain, it is imperative that suppliers and producers work together in a coordinated manner. This means rapid flow of information between customers-producers-suppliers, distribution centers and transportation systems, which enables some companies to create highly efficient supply chains. Suppliers and producers should have the same goals. They should have mutual trust in terms of product quality, service, capability, and contract obligations. In addition, they need to participate in the design of the supply chain in order to achieve common goals and facilitate communication and information flow. Some companies try to gain control over their supply chain by moving toward vertical integration- by utilizing the ownership and integrity of all components along the supply chain from the provision of materials and services to the delivery of the final product and customer service. But even with this kind of organizational structure, different activities and operational units may be inconsistent. The organizational structure of the company should focus on coordinating different activities to achieve the company's overall goals.

Generally, each supply chain consists of the following components which are depicted in Figure 2-1 from upstream flow to downstream flow:

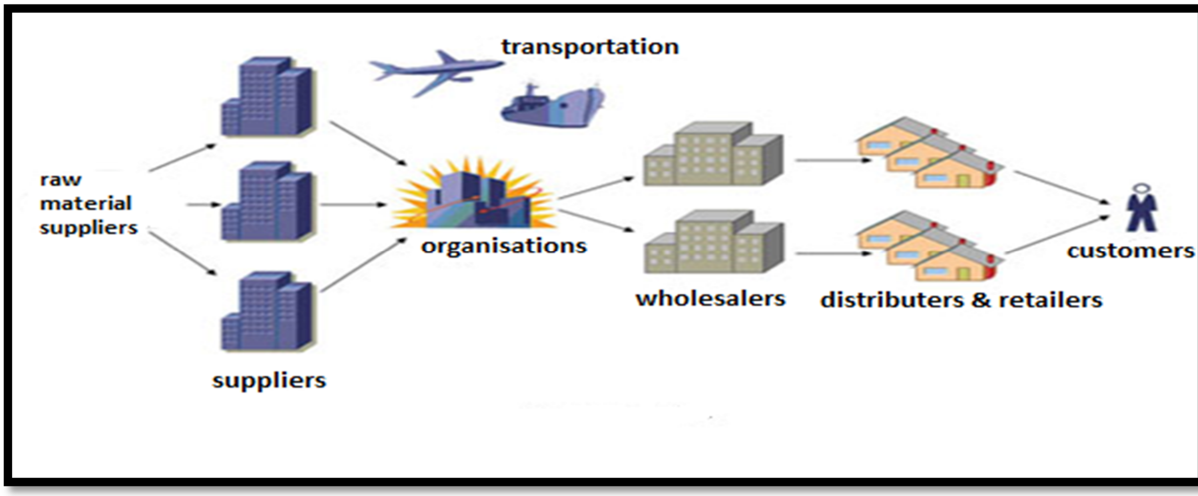

Figure 2-1: forward flow of supply chain

As outlined here, for the effective and efficient management of this chain, the integration and coordination of the chain activities must be considered, and we will continue to express these two components.

2.1.4 Supply chain management and its components

According to what was mentioned in Section (2-1-3), two main components of supply chain are integration and coordination that we are going to explain in this section.

2.1.4.1 Main Components of Integration:

1-partners selection

2. Organizational networking and inter-organizational collaboration

3. Leadership

Criteria for selection of partners in the supply chain are as follow:

1-price

2. Specialized knowledge

3. Commitment for participation

4. Proper culture

Regarding to “organizational networking and inter-organizational collaboration”, it should be considered in mind that, although entities within the supply chain are legally independent, they are dependent economically with each other and each supply chain will be stable in case of win-win approach.

Leadership is about decisions made for the entire supply chain, such as corporate deletion or integration of a new company. Leadership may be a central company or a leadership committee that consists of representatives from all members of the supply chain.

2.1.4.2 Main components of coordination

1. The use of information and communication technology

2-Processism

Using a computer instead of manually executing tasks from the moment the order is placed up to receiving and checking the shipments increases the speed and decrease the error rate.

The important thing to keep in mind is that the supply chain must have a meaningful link in its process with the real world. Indeed, the supply chain must be process-oriented. In addition, in order to synchronize the supply chain activities as much as possible, it is necessary trying to make process-oriented thinking an alternative to traditional task-oriented thinking, because by looking at the process, the organization's activities will cause repetitive activities to be reduced and increase the efficiency and effectiveness of the organization. Therefore, with regard to these two components of the supply chain, the supply chain management objectives should be proportionate to these two components. These objectives will be further expressed.

2.1.5 Supply Chain Management Objectives

-reduce costs or reduce inventories

- Increased accountability/responsibility for customers

- Improved supply chain communication

- Reduce the cycle time of production

- Improvement of coordination.

2.1.6 Main Processes of Supply Chain Management

Supply chain management has three major processes:

1- Information Management

2-Logistics management

3. Relationship Management

1- **Information Management**: Today, the importance of information is obvious to everyone. Proper data transfer make processes more efficient, and leads to better management. In the supply chain area, the importance of coordination in activities is very essential. Proper information management between partners will increase the impact on speed, accuracy, quality and other aspects. Correct information management will lead to more coordination in the chain. Generally speaking, in the supply chain, information management will causes some competitive advantages in different sectors, such as: Logistics management (transfer, processing and access to logistics information for the integration of transportation, ordering and manufacturing processes, order changes, production scheduling, logistics programs and warehousing operations); communicating and processing of data between partners (such as communicating and processing of technical information, orders ...); collecting and processing information to analyze the process of evaluating, selecting and developing suppliers, collecting and processing supply and demand information, predicting market trends and future conditions of supply and demand, and improving relationships between partners .

Obviously, information management and supply chain information systems can impress internal decision making processes of the different supply chain segments, which indicates the importance of this component in supply chain management.

2-Logistics management: This section, which includes all the physical activities from the raw material up to the final product including transportation, warehousing, production scheduling, etc., provides a fairly large part of the supply chain activities. In fact, the scope of logistics is not just the flow of materials and goods, but the core of the supply chain activities, in which relationships and information are supporting elements for improving operations.

3. Relationship Management: The factor that leads us to the end of the discussion and perhaps the most important part of the supply chain management for its construction and form, is the management of relations in the supply chain. Relationship management has a tremendous impact on all areas of the supply chain, as well as its level of performance. In many cases, the required information and technology systems for supply chain management activities are readily available and can be completed and deployed within a relatively short period of time. But many initial defects in the supply chain are due to the weak transfer of expectations and the result of behaviors that occur between the parties involved in the chain. In addition, the most important factor for successful supply chain management is the trustworthiness of the partners in the chain, in such a way that partners have mutual trust in each other's capabilities and operations. In short, in the development of each integrated supply chain, the development of trust and confidence among partners, and the credibility of them, are critical and important elements for success.

2.1.7 Supply Chain Problems

- High variety of Decision making centers: Due to the fact that various supply chain organizations are involved, coordination in the supply chain in order to make them consistent and univocal requires a high effort.

- Uncertainty: the main source of supply chain forecast is uncertainty in demand. Demand forecasting is affected by several factors such as competition, prices, current conditions of the company and its positioning, technological development, political changes, and the general level of customer engagement. Another factor is the uncertainty of supply chain delivery times that depend on factors such as the failure rate of machines in the linear production process, the traffic congestion involved in transportation, and the quality-related material issues that may cause delays in production.

- Disconformity: These types of problems occur when a part of the company is not well-connected with other sectors. When the message is incomprehensible to business partners, and when the company's departments are unaware of some issues, or too late about what is needed or what should happen. Some examples of this issue are: bullwhip effect and misplacement.

2.1.7.1 Misplacement

This problem occurs when customers want a product that is unavailable. However, it actually exists, such as when the product is placed incorrectly or the amount of the store is incorrect.

2.1.7.2 Bullwhip effect

The unmanaged supply chain is not absolutely stable. The form that has been repeatedly seen in the untapped supply chain is the bullwhip effect. This creates fluctuating effects in the supply chain, which is the main factor behind the changes in demand. When moving from a customer level to a higher level in the chain, it is seen that small changes at the low level make major changes at the higher level of the chain. Finally, the network can fluctuate greatly. Any organization in the supply chain tries to solve the problem from its point of view. This phenomenon is known as the bullwhip effect which is considered in all industries and shows its effect through increased cost and weaknesses in service levels.

2.1.7.2.1 Causes of the occurrence of the bullwhip effect

- Price fluctuations

- Periodic Ordering Policies

- Production scheduling based on wholesalers forecasting demand rather than forecasting customer demand

- Demand fluctuations, quality problems, strikes, factory fire

- Delivery time

- Upgrading and updating demand forecast

2.1.7.2.2 Counteracting the Bullwhip effect

Based on studies of D. Aprile [66]has suggested some actions to reduce the bullwhip effect which are following.

1. Reducing uncertainty: Companies can reduce uncertainty by sharing information along the whole supply chain, providing each phase with complete information on actual customer demand, and reducing reliance on forecasting (relying more on direct demand data).

2. Reducing variability: Variability inherent customer demand process can be reduced by drastically decreasing price promotion, using a consistent price strategy, which means offering a price as low as possible every day, without periodic price promotion

3. Reducing lead-time: Lead-time could be reduced by adopting lean manufacturing and reducing costs of batching orders. The variance of orders is dependent by lead time. EDI (Electronic Data Interchange) can significantly reduce order lead time which is one of the components of the total lead time between two supply chain stages. Therefore, companies should realize that greater savings could be realized by implementing computer order system, allowing administrative costs deduction (small orders).

4. Strategic partnership: adopting strategic partnerships, for sharing information and effective inventory management along the whole supply chain, can significantly reduce the bullwhip effect. One of the best strategic partnerships is the VMI (Vendor Managed Inventory): manufacturer manages its inventory product at the retailer outlet, and deciding how much inventory to keep on hand and how much to ship to the retailer in each period.

2.1.8 Benefits of the supply chain

- Reduce logistics costs, and maintenance

- Reduce personnel

-productivity Improvement

- Improving the financial cycle

- Timely delivery

- Information clarity and flexibility

- Standardization

- Globalization

- Saving scale

- Increasing the power of customer selection and access to suppliers

- Reducing distances

2.2 Logistics

2.2.1 Introduction

Logistics is one of the most important and influential processes in the supply chain management, and in fact the logistics of the supply chain are the core of its activities. And generally, logistics has two generic categories: direct logistics and reverse logistics. In the following, given that the logistics category is one of the important issues in supply chain management, we will state that in this chapter by logistics term we mean direct logistics and in the next chapter we are going to introduce reverse logistics.

2.2.2 Logistics

Originality logistics word is the English term with the Greek root "Logistikos" [67]. This term in ancient Greece means the calculus used in the military and logistical affairs of the army. The logistical officers of the Romanian and Byzantine Armed Forces were called “Logista”. It has been used more or less in support of military units throughout history. In the eighteenth century, the French officially introduced the term in their military terms. Antoine Henry Gomini, a French author, first described it in the book "The Art of War" in 1838, an appropriate definition of the logistics: "logistics is the scientific art of the movement of the armies," and later the English used it in their military units. Finally, in the first and second world wars, the logistics in military forces and organizations in most countries of the world was effective, but with a variety of meanings and areas of performance.

2.2.3 Different definitions of logistics

Logistics relates to the planning and control of the flow of materials and related information in organizations, both in private and in the public domain. In the field of military science, logistics is related to providing troops with food, weapons, ammunition and other parts, as well as the transportation of its soldiers. In civilian organizations, logistics issues have been raised in the manufacturing and distribution companies of physical goods. And the basic issue of decision making is related to the timing and manner of buying, storing, transporting and storing raw materials, manufactured goods and semi-manufactured goods. [68]

Logistics is like a pipeline that delivers products and services in any place of the world. Logistics specialists manage and coordinate activities on this global pipeline to provide an efficient and effective flow of materials from the time we receive a needs to the time we deliver the need. A number of logistics activities include: shipping, purchase, warehousing, material handling, strategic planning, inventory control, and forecasting.

The goal of these logistics activities is to meet the needs of end-users. And supply chain managers are trying to deliver the right product at the right price and in the right situation to a definite customer at a specific place, time and expense. A more comprehensive logistics definition is provided by CLM (Logistics Management Association) which states that logistics is that part of the supply chain process which Plans, implements and controls the fulfillment of the needs and wishes of the customers through an efficient and effective flow of materials and the storage of goods, services and information from the point of origin to the point of consumption. [69]

According to the above definitions, logistics is related to all activities of the supply chain from the moment the raw materials are delivered to the moment the delivery of the product or service is made to the customer. Although in most cases, logistics and supply chain are used instead of each other, we will continue to differentiate between them.

2.2.4 Differences in logistics management and supply chain management

The concept of "supply chain management" is defined by the integration of logistics services throughout the supply chain towards the integration and management of key business processes in the open supply chain. Based on the definitions of supply chain management and logistics, we conclude that these two concepts do not differ much from each another and are often used in resources rather than each other. However, it is better to use each of them in its exact sense. because logistics is a subset of supply chain management which concentrate on scheduling , Controlling and application of efficient and effective flow of goods, storage, transportation, and related Services from starting point to the final point of satisfying customer's needs.

2.2.5 Logistics management areas

-Logistics within the borders of a country

-Internal logistics

-Logistics beyond the borders of the country

2.2.6 Logistic Performance Index (LPI)

Logistics Performance Index consists of 6 sub-indicators as follows:

1. Efficiency and clearance of procedures (speed, simplicity and predictability of customs formalities)

2. The quality of commercial and relocation infrastructure (e.g., entry ports, railways, roads and information technology)

3-Ease of access to various goods at competitive prices

4. Competency and quality of logistics services (carriers, 3th parties' providers or customs intermediaries)

5. Ability to track sent goods

6. Suitability of the delivery time to the customer at the scheduled time or expected time

2.3 Reverse Logistics

2.3.1 An introduction to reverse logistics

One of the issues that arise today in the field of logistics and supply chain management in different industries is the issue of "reverse logistics" and "returns management"; something that seems to have not been considered seriously in the various industries so far. Over the past two decades, many companies and industries from developed countries have begun researching on reverse logistics as one of the key processes in their supply chain. Even recently, an ISO certificate on returned processes has also been received by some advanced companies. Today, in the developed countries of the world, the focus point of work, industry, government, business and service organizations is on reverse logistics processes and closed loop supply chain, which are seen as the basis for creating real economic value of goods and services, along with supporting environmental considerations. . This focus is now growing on all markets, including industry and advanced technology, business and consumer products.

What is happening in the traditional flow of the products, and industry leaders emphasize on its control and management, is the direct or forward flow of materials and products, mainly from suppliers to manufacturers, distributors, retailers and, ultimately, customers. But in many industries, there is another important flow of supply chains that are reversed and where products from lower supply chains are returned to higher levels. Reverse logistics seeks to investigate and manage reverse flows, or, in other words, reverse flows in supply chains.

Reverse logistics management and closed loop supply chain are one of the vital aspects of any business and involve the production, distribution, and support of any kind of product. In the current era of consumer products which products life cycles are becoming shorter and shorter, product recycling policies are defined with quick response times and customer service, and more emphasis is placed on return management, reshaping and reposing of goods. It's over there. New government laws and green laws that address the removal and disposal of electronic wastes and other hazardous materials also force top managers and logistics managers to ensure that supply chain processes look closer to the reverse logistical processes.

2.3.2 The history of using reverse logistics

The reverse logistics has existed since its inception in various forms in the military organizations of the world, but in the past, military organizations did not pay much attention to reverse logistics for several reasons and may have thought that the reverse logistics is an ambitious dream or a category which requires advanced technologies.so, it leads to preventing the development of military units. In many of these organizations, reverse logistics was not considered as a principle in functional reviews and analysis of their issues. Because at a time when an army unit carried out reverse logistical activities, it did not have any financial benefit for doing so, which perhaps limited ability and the lower military force's risk, among other factors, was another reason of ignoring logistical activities. But in recent years, commanders, managers and officials of military organizations have been looking for reverse logistics with the use of methodology of management process, and industry has paid a lot of attention to reverse logistics. In Europe, companies and institutions have found that the use of used products and reuse of packaging (reverse logistics) helps to improve profitability and reduce environmental damages. In the past ten years, the information resources and books needed in the field of reverse logistics, a new and emerging topic, were very rare and scarce. But today, there are many booklets and books that have been devoted to this topic. Undoubtedly, today, by designing new theories in relation to customer satisfaction, production based on the needs and customers' requirements and competitive issues in the market, on the one hand, and on the other hand, profitability for major producers, such as large automotive companies and companies with the vast chain that is physically and geographically widespread, as well as the influence and expansion of information and communication technologies, and the kind of dependency which exists between large suppliers and producers; bring this topic to an important and significant discussion.

2.3.3 Reverse logistics definitions

Reverse logistics relates to all operations referred to the reuse of products and materials. Reverse logistics is the process of planning, deploying and controlling efficiently, efficient flow of material costs, current inventory, manufactured goods, and relevant information from the point of consumption to the main point of the chain with the goal of rehabilitating it or its proper disposal. Re-production and re-activation may also be included in the reverse logistics debate. Reverse logistics, in addition to reusing and re-packaging the materials, involves re-packaging design for less material use, and reducing energy consumption and shipping-related pollution. Although these items are important processes of reverse logistics activities. But it's better to be placed in the green logistics. If no goods or materials are sent and returned, then our activity is probably not a reverse logistics activity. Reverse logistics also includes the processing of returned goods for damage, seasonal inventory, re-stocking, repossession, re-inventory and surplus inventory. Also, reverse logistics involves planning for product revitalization, critical and hazardous substance planning, fully resetting equipment and restoring physical assets. [70]

2.3.4 Reverse logistics processes

The main processes of reverse logistics based include:

-Collecting

-Inspection, selection, sorting and classification

-reprocessing (including repair, refurbishing, remanufacturing, retrieval, recycling and incineration), or direct recovering

-Redistribution

Which are expressed in Figure 2-2 [71].

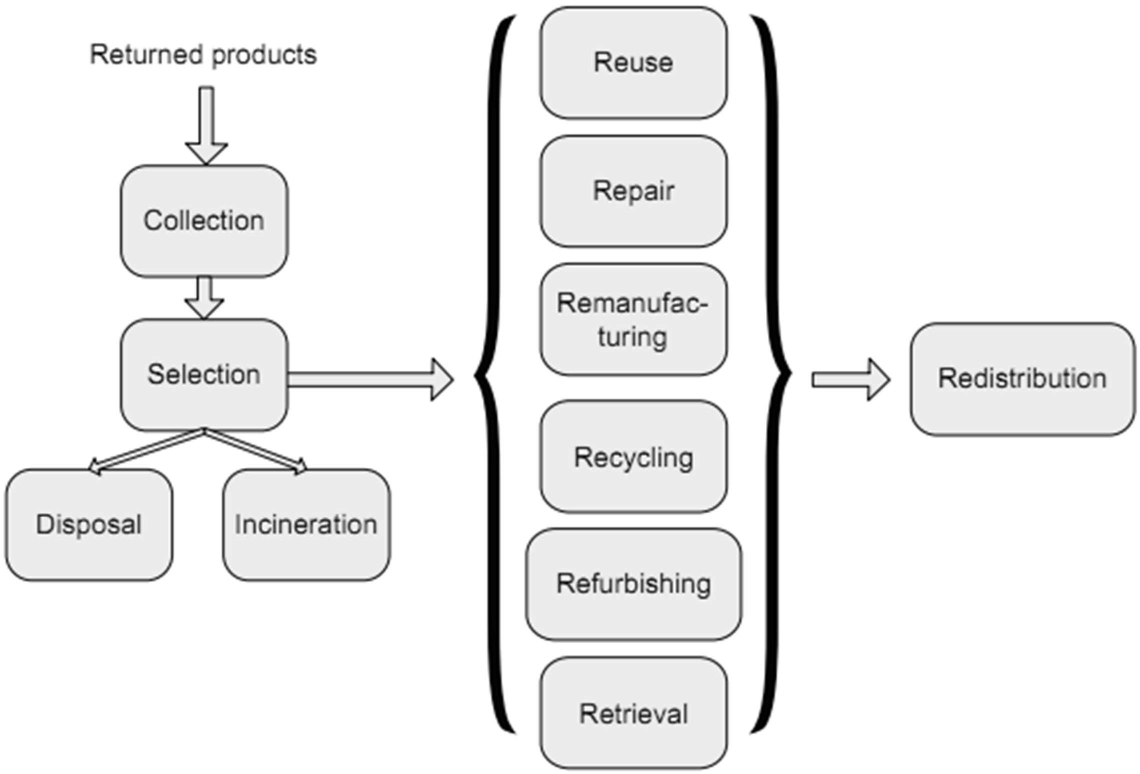

Figure 2-2: Product flow in reverse logistics

In ***collection***, used products are transferred to a place for some specific treatment.

In ***inspection and separation/selection***, products are inspected and separated by some criteria such as: their reusability and how they can be reused. Inspection and separation include some activities such as disassembly, shredding, sorting, testing, and storage.

Reuse shows whether products still have enough quality and are in good enough condition that they can be used again. For example: reusable bottles, containers, and most rented facilities.

In ***reprocessing***, used products are converted into a usable product. This can occurs at different levels: material (recycling), component (remanufacturing), product (repair), selective part (retrieval), module (refurbishing), and energy (incineration).

In ***recycling***, product forms are turned into more basic forms such as scrap metal, glass, plastic, and paper.

In ***remanufacturing***, a product in whole or in its part is used to create a new and usable product. Some of these operations include cleaning, disassembly, replacement, and reassembly.

In ***repairing***, broken products have some aspect of their life cycles restored, possibly with a loss of quality and so, they are going to be repaired.

Refurbishing relates to upgrading a product.

In ***incineration***, products are burned and the released energy from them is captured.

In ***disposal***, useless products that cannot be reused because of technical or economic reasons are discarded and vanished.

In ***recovery/retrieval***, used materials are captured, repaired, and remanufactured, a process which adds value.

In ***redistribution***, products are distributed to different markets and places. This operation is consist of storage, sales, and transportation.

2.3.5 Differences between Green Logistics and RL

RL is related to recapturing the value of goods at their destination, while green logistics (ecological logistics) could be defined as understanding and reducing the ecological impact of logistics. It includes measuring the environmental effects of particular transportation modes, reducing the usage of energy and materials in logistics activities, and following the guidelines of ISO 14000. In fact, green logistics takes into consideration environmental aspects to all logistics manners and especially on forward logistics. Environmentally manufacturing is more than just manufacturing for forward logistics. It is manufacturing which is concerned with the environmental impacts of products until the ends of their lives. [72]

2.3.6 Differences between Forward and Reverse Logistics

As we shortly introduced before, here we are going to compare forward logistics and reverse logistics by determining the differences between them. Which is shown in Table 2-1. [73]

Table 2-1: differences between forward logistics and reverse logistics

Forward logistics	Reverse logistics
1. Prediction is relatively straightforward.	1. Prediction is more difficult.
2. Transportation is one to many.	2. Transportation is many to one.
3. Product quality, packaging, and pricing are relatively uniform.	3. Product quality and packaging are not uniform.
4. Destination, routing, and disposition options are clear.	4. Disposition and destinations and routing are unclear.
5. There is a standardized channel.	5. Deviation based in channel.
6. Accounting systems closely monitor forward distribution expenses.	6. Measuring reverse expenses usually is impossible and many items determine pricing.
7. Inventory management is congruous.	7. Inventory management is not congruous.
8. Product life cycle is controlled.	8. Estimation of product life cycle is more difficult.
9. Transactions between parties is straightforward.	9. Extra discussion brings about complexity in transactions.
10. Real-time data is easily available to track product.	10. Process is invisible.
11. There are clear marketing methods.	11. Complexity in marketing.

2.3.7 Reverse and direct logistic model (closed-loop supply chain)

Regarding reverse logistics and forward logistics cycles, in Figure 2-3 a schematic view of integrating these cycles together are demonstrated. Undoubtedly, without identifying these flows properly, it is not possible to effectively manage a closed-loop supply chain operations. Therefore, returns collection & selection centers ,which focus on collecting returns and select the right operation for used products to know which RL operation and to which entity they should be transferred to accomplish the correct operation, plays an important role to effectively connect and improve these cycles.

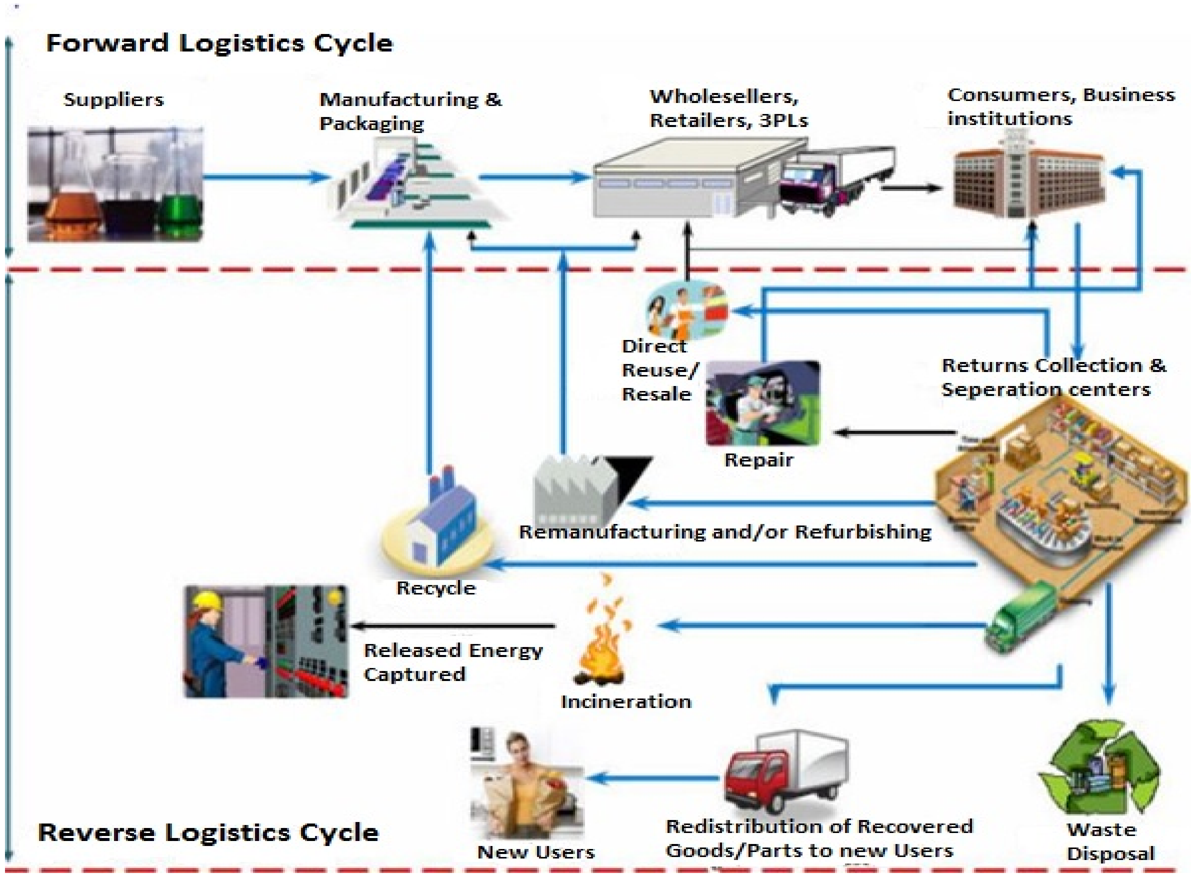

Figure 2-3: schematic model of closed-loop supply chain

2.3.8 Separation of activities in reverse logistics and direct logistics

Regarding the activities mentioned in the reverse and forward logistics in the Table 2-2, there are three distinct flows in common: the flow of information, the flow of goods and the flow of liquidity. In the area of information flow, one of the requirements of Reverse logistics management is the identification of those chain-based information flows that facilitate and accelerate processes in the supply chain. Efficiency in the processing of information related to returned goods will inevitably lead to optimization of inventory management, repairs and after sales services. Regarding to material flow, the company must always pay attention to the direct flow of goods in the chains much more than its reverse for predicting and planning because it's prerequisite is demand estimation and production capacity. But in the case of returned goods material flow and the way of managing them, there is always uncertainty about the number and type of goods, and therefore it's needed to be predicted accurately by using the existing information processing systems for returned goods. Therefore, the company will be able to extract the required information from different parts of the chain and implement them for reverse logistics optimization by creating a transparent image of the process of returning goods in the organization. Integrating information both in the main supply chain and in the reverse chain reduces the rate of returning goods and increases productivity. Liquidity flows in reverse supply chains are usually reflected in credits, discounts, and cost savings. Therefore, the creation of monetary and credit policies helps us to manage liquidity flows. Regarding this, taking advantage of the customer relationship management approach in the process of returning goods can have a significant impact on maintaining and creating loyalty in customers.

Table 2-2: separation of activities in RL and direct logistics

Forward logistics			**Reverse logistics**
New product development	Material management	Production & distribution	After sale services
-Design development -Technologic roadmap -Mechanical design -Prototype making -New product introduction	-Customer relationship -planning -procurement -inventory planning -parts manufacturing	-Parts assembling -sample(primary) production -final test -transportation and delivering to customer	-return products processing - return centers management -management of return referral to sellers -management of returned products flow -product recycling -testing operation, repairing, or recycling -inspecting, repairing, and recovering in order to resell to product

2.3.9 A review on various aspects of reverse logistics

By analyzing the following three points, we want to determine why the materials are returned, which of them are returned, and how they are returned. We will mention the driving forces behind the associations and active them in RL; what being returned, then we will explain the products characteristics that make a recovery appealing or obligatory; also, we will express, who involves in this processes.

2.3.9.1 Driving Forces behind reverse logistics

The forces which drive RL are categorized under three headings: economics, legislation, and corporate citizenship.

1. Economics may provide some straight benefits to corporations by their choice of input materials, decreased expenses, and value-added recovery. Indirect benefits to companies include anticipating and impeding legislation, protecting markets, fostering a green image, and improving supplier-customer relations.

2. Legislation: in a series of laws in some countries, a company is obliged to recover its goods or accept its returning.

3. Corporate citizenship constitutes a set of values that force a corporation to behave responsibly in reverse and green logistics.

2.3.9.2 Reasons for return

Generally, regarding studies of Dekker et al. (2002) [74] we can categorize returns into 3 types:

-manufacturing returns

-Distribution returns

-Customer returns

Manufacturing Returns

Manufacturing returns are those products which are recovered during production. These contain the following:

- Surplus raw materials

-Quality Control returns

- Production leftovers and by-products

Distribution Returns

After goods/products are produced in a factory and transferred into distribution, some products return to production, including the following:

-Product recalls due to safety or health problems.

-Business-to-business (B2B) commercial returns from buyers due to contractual options that allow the return of products because of damaged deliveries or unsellable products.

-Store adjustments, including expired products.

-Functional returns or materials used as carriers to handle and transfer products in distribution such as pallets.

Customer Returns

Generally, Customers return products for the following reasons.

-Reimbursement guarantees allow customers to change their mind regarding unmet product requirements.

Warranty returns allow the return of products because of discovered problems during usage.

End-of-use (EOL) returns include products such as bottles that cannot be used again but are returnable.

2.3.9.3 Characteristics and Types of Returned Products

M. Fleischmann et al, (2003) [75] showed that the characteristics of returned products/parts are very important. Three main relevant aspects are composition, use pattern, and deterioration.

Composition

Elements of composition which are of concern to the manufacturer of a returned product include the following:

-*disassembly easiness*: like removing some small pieces of old electronic devices, which can be reusable.

-*Homogeneity of constituent elements* is related to products that contain dangerous material which must be removed before they can be recycled (e.g., batteries).

-*transportation easiness:* is related to the specific transport of certain products. These products require separate distribution systems to avoid contamination from old products.

Use Patterns

Patterns of use can be divided into two issues which are: place of use, and length and intensity of use.

- For place of use, if a product is applied in various usages and different places (e.g. frequently used in different places), its correction operation will be more difficult. Consequently, the collection difficulty is directly related to the number of use place.

- If the length & intensity of use is short, then the product/part can be reused without the recovery.

Deterioration

At the end of a product's use, how much functionality remains with the product in whole or in part greatly determines the recovery option. These aspects have several important roles which are the following:

-*Through inherent deterioration*, some products/parts are used completely during their use (e.g., gasoline), or they lose their useful life quickly (e.g., batteries).

-*Fixability* shows how easily a product can be improved, modified, or refurbished to a better condition (e.g., rechargeable batteries are easily restored).

-*Homogeneity of deterioration* is a measure which shows whether all parts of a product age are equally or not. This one directly affects the method of recovery.

-*Economic deterioration* is a measure of a product's economic functionality which express, as it expires will it become obsolete?

2.4 Information technology (IT) in reverse logistics

2.4.1 The necessity of using information technology in reverse logistics

Today, due to increased business competitiveness, especially in the field of logistics activities and increasing the cost of access to resources, the importance of optimal use of all organizational sources has becomes apparent to all companies. On the other hand, concerns about the environment and the financial attractiveness of reusing parts and products has led to popularity of reverse logistic. Therefore, organizations have to make short, medium and long term decisions in order to stay competitive and increase the speed of responding to their customers. Therefore, managers in order to decide on these areas require accurate and up-to-date information.

In the field of reverse logistics due to the poor quality of information and the lack of integration at different levels, making decisions in order to improve RL performance and aligning it with direct logistic is difficult and costly. Therefore, organizations try to facilitate these things by taking advantage of all possible factors.

In today's growing world, communicating and exchanging information with suppliers, producers, and customers is not possible without the help of IT. The use of electronic technologies has a long history and e-commerce means sharing business information, maintaining business relationships, conducting business negotiations and resolving issues, and implementing agreements by Remote networks such as Internet are intended to achieve business transactions. Also in e-commerce, the continuous use of information and communication technologies is emphasized from the beginning point to the end point of electronic business chain.

Information is one of the most important components of each chain. Coherence is a fundamental part of supply chain management and decision-making, which is also based on information.

Today, the need for accurate information in the short run is a must-be in any economic activity. More importantly, ensuring proper information support is a management imperative in the supply chain. Therefore, two factors of information technology and e-commerce can further facilitate reverse logistics management.

Information technology can affect the speed, time and cost of activities. In general, information technology provides three types of changes in an organization:

- Replacing (automating existing processes)

- Support (possibility to assist existing processes, such as decision making and communication)

- Innovation (the ability to create new methods)

However, it's important to see what information interactions are between the direct and the reverse, and how IT systems can support them. Generally, in order to implement effectively reverse logistics, adequate and accurate information is required in addition to information systems. Therefore, we will examine three related issues in the sub-sections below. Firstly, it is important to look at technologies which focus on collecting qualified information regarding to the entry of product in reverse logistics network, as well as the information needed for reverse logistics operations. Then we discuss the interaction and exchange of information between reverse logistics and forward logistics systems. Finally, we discuss on some new technologies/platforms, which possibly have many capabilities for reverse logistics systems.

2.4.2 Collection of required information and information flows in reverse logistics chain

In general, it's important to know what product, where, when, and under what conditions would return. Particularly, for business returns, we need to know the full conditions of the product, as well as for particular products, which have high value and short life cycles.

Several ways are implemented to collect product information, such as product catalogs which can provide a clear presentation of product information, retrieval, service categorization and instructions. Another way is putting information in the product. In fact, technologies such as bar codes and radio frequency identification (RFID) frequency may be used to support this feature. The two-dimensional bar code allows us to place more information in a bar code than one-dimensional systems such as UPC. This software supports not only a code but also other high-capacity text descriptions and data. It also detects the radio frequency using a small radio transmitter that is installed in each product. This label can have some memory capacity to store data. The battery is strong enough to send a signal for many years and the signal is strong enough to be received by receivers. Hence, the after-sales product also has marketing opportunities to influence the return of products.

To understand the information needed by the e-market for returns, we need to look at the processes and operations involved in managing returns and identify their various aspects supported by IT processes.

Reverse logistics network operations require both physical processing and information processing for returning inputs. During collection operations, for example, returns are collected and classified according to their performance and status. This operation and its information flows are presented in a study by Kokkinaki, et al. (2002) [76] in Table 2-3. This operations in reverse logistics network are listed by some information which are as input in the next operation or cause subsequent operations in the network.

Table 2-3: information flows for RL operations

Reverse logistics operations	Information input	Information output
collection	Historical data Location of the Collection Center	Identification of the return(s) Quantity Place of origin Timestamp
Selection	Identification of the return(s) Quantity	Configuration (BOM) Quality assessment Remaining value estimation Reuse, remanufacture or recycle?
Reuse Remanufacture	Identification of the return Quantity Configuration of the return (BOM) Quality assessment Remaining value estimation	Bill of Recovered Product/Parts Quality Grade(s) Price Quotation(s)
Recycling	Identification of the return Quantity Configuration of the return (BOM) Remaining value estimation	Bill of Recovered Parts/Materials Quality Grade(s) Price Quotation(s)
Redistribution	Bill of Recovered Product/Parts/Materials Quality Grade(s) Price Quotation	Invoice Info
Disposal	None	None

Operation in reverse logistics network can have more effective planning and control, if there is enough information available in returns. For example, routing for collecting returns can be optimized if the original location and timing of returns are already known. Added value of electronic market can be obtained in several ways, such as:

- As a consolidation channel (unit) for a series of returns from electronic market is strongly demanded.

- accessing Information from users about received returns.

-motivating customers to follow recovery policies and optimization of their returns

- Facilitating better planning and control of returns.

- Facilitate the re-identification of recovered products or parts in the main markets or secondary market

2.4.3 Interaction between direct and reverse logistics in IT systems

The necessity of coordination between direct and reverse logistics processes leads to interactions and trade-off in IT systems. A study by Kokkinaki et al, (1999) [77] noted that business processes between business partners in forward supply chain for electronic transactions and network configuration, respectively, are supported by EDI(electronic data interchange) and Value Added Networks. This connection, also known as extranet, is often described as electronic business to business (B & B) and network infrastructure. EDI systems allow business partners to fully exchange electronic information in a complete and accurate way, and provides a range of different transactions for a variety of business activities. EDI applications are based on structured protocols, scheduling sequences, and bilateral information exchanges, consequently using backup software from interactions is necessary. The traditional EDI system has been criticized for being expensive in terms of initial investment in infrastructure, software and education. In addition, due to its structure, this structure creates and maintains continuous relationships between its well-known business partners, leading to the creation of a closed association.

Addressing these technical barriers has led to the emergence of standard XML or electronic data interchange systems that provide solutions to integrate EDI applications with the Web. Benefits of this structure are lower costs, easier introduction of new business partners and increased business activity. In reverse logistics, XML or EDI can be a tool for interacting with information technology systems specifically for reverse logistics and EDI systems that are still used in forward logistics. In sum, there are many different types of systems and operating systems that are used to serve different business needs, as shown in Figure 2-4.

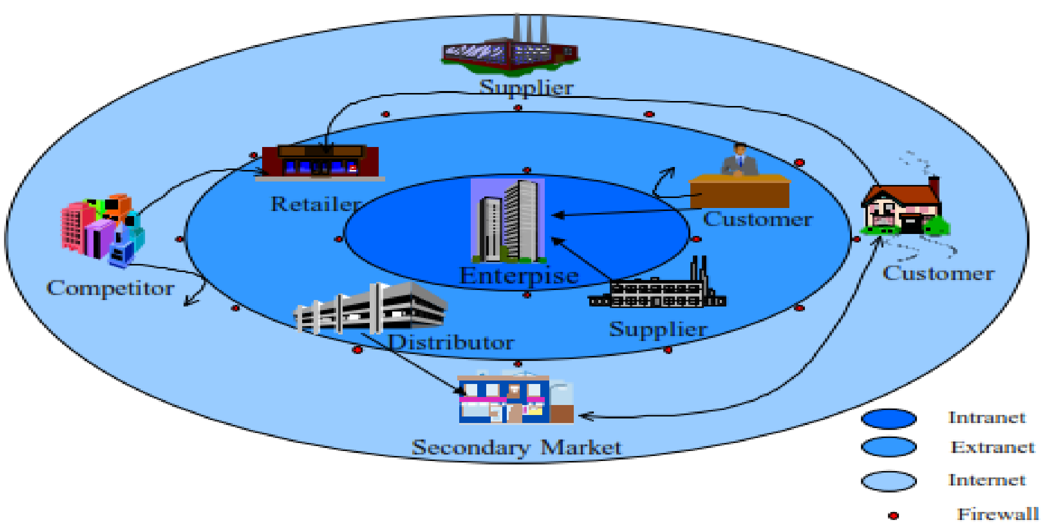

Figure 2-4: IT systems for forward and reverse logistics

Figure 2-4 shows three levels of network infrastructure. Firewalls may be implemented by providing security systems. Organizational access is prohibited from other outside organizations, while communication with business partners (organizations in the loop) is supported through the network structure.

2.4.4 The Role of ICT Systems in Reverse Logistics

In this section, we examine the uses of ICT in support of reverse logistics activities. Most ICT systems which are designed for reverse logistics are for responding to specified needs (for example decision making on different alternatives for returning used products, and product design with the best recovery capability after the end of life) or to cover all the company's specific reverse logistics needs. So, for systematic coverage of this section, we need to create an infrastructure. To this end, we revert to the essential requirements of reverse logistics.

The main issue in reverse logistics is related to product revival with the aim of creating possible situation for returning them to the market. Accordingly, the three important issues that ICT systems in reverse logistics should address are the following.

-Product data, including data related to the type and the way of returns

-Process facility, especially supporting of reverse logistics activities

-Re-distribution on the market, and in particular, attempts to integrate diffused market

The existence of information is a necessary component in management of returns. However, there are some defects in planning returns due to existence of high uncertainty in some important characteristics such as place of origin, returning time, and quality. Since information referred to Returns are rarely available, ICT systems are emerged to either aggregate required information from the systems which already been used to record returns data or re-obtaining data in some cases by reverse engineering.

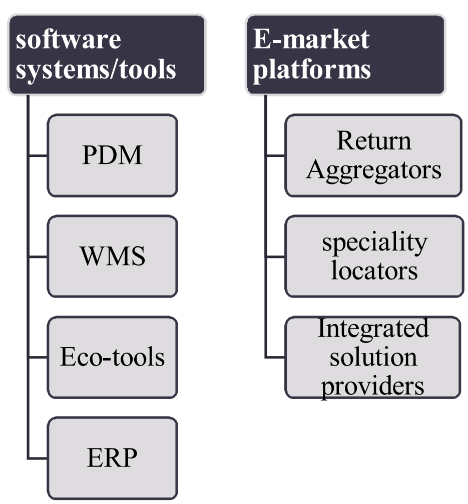

Figure 2-5: categorization of effective ICT Systems and platforms in closed-loop supply chain

ICT systems which are useful for controlling and coordinating reverse logistics processes, are applicable either in decision making about choosing an appropriate recovery method (reusing, remanufacturing, and recycling) and, as well as, supporting managerial activities associated with returns that lead to better management.

After accomplishing the necessary changes, used parts and products must be returned to market. It is noteworthy that such markets that want these products are very fragmented and non-coherent. In recent years, with the expansion of using e-commerce, many efforts have been made to integrate such markets by building professional e-markets.

Products, processes, and markets are 3 main pillars of closed-loop supply chains. In this study, in order to create a systematic view about how ICT systems process and handle related information flow, we are going to use Figure 2-5 as a roadmap. Firstly, we should identify the constraints imposed on each of these flows; for example, we introduce the effect of uncertainties on products, processes, and markets. Then, by using this roadmap we describe shortly each of presented systems/platforms.

2.4.4.1 Problems related to uncertainty

In this section. We address the uncertainty issue and how it occurs in the reverse logistics network. As we discussed already, planning logistics activities require information processes time, delivery times, returns after the end of product, customer demand, product quality, etc. In scientific literature, the issue of "uncertainty", regarding these reverse logistical variables have been approached in the abundance of studies and some solutions have been presented for example in studies of Fleischmann et al (1997) [78] and Thierry (1995) [79]. The purpose of this section is to clarify the causes of uncertainty in reverse logistics networks.

RL networks are part of the demand and supply networks. In many studies of operations research, uncertainty is defined by concepts of probability theory. Uncertainty arises from the fact that a decision maker cannot provide suitable information quantitatively and qualitatively for the elaboration and definite prediction of behaviors and patterns.

Zimmerman (2000) [80] has emerged the causes of uncertainty, various types of uncertainty, and uncertainty models. Without going deeply in detail, some of the causes which lead to uncertainty are:

- Lack of information

-information frequency

-inconsistent observation data,

-ambiguity

Some examples of each of these factors occurring in reverse logistics networks are:

Lack of information: planning in a rework production line may be subject to lack of information about quality of returned copy machines.

Frequency of information: A computer technician may have not enough time to read all the repair history of the server in order to decide about the replacement of a particular piece.

Inconsistent Observations: An engine that has a very long life may greatly reflect the results of the test.

Ambiguity: eligibility to obtain a reusable title for a computer monitor may be referred to several causes like rebuilding, scrap or material revival.

But we need to differentiate between the situation where the information is not needed and the situation where this information is not available to the decision maker. Uncertainty, as defined here, confronts the decision maker with a variety of options, the decision maker may invest in, or may change information systems which works better to achieve information (such as bringing uncertainty using From the possible literature).

Here is a brief glimpse of the uncertainty factors in RL networks and we examine the effect of them in a qualitative way. We also discuss some of the solutions that the decision maker can apply. It should be noted that here we have implemented categorized ICT model which was previously presented in Figure 2-5

Product information: design of the product affects the uncertainty of the product quality. Quality of product, pieces or material is high enough when it is able to be assigned to a reusable alternative with high value added. For example, the product which has a high possibility to remanufacturing, is assumed to have a higher quality than the product that only its raw material could be recycled. Standard methods for specifying product quality (such as efficiency) usually are consistent with this method. Numerous specification design of parts, has a negative effect on product quality. For example, an electronic device may contain a large number of components, so that the place of parts in disassembly process may be impossible. Modular design of products can have a positive effect on the reuse of practical parts if the product is not needed to be updated.

Process Support: Logistics processes are affected by uncertainty. We concentrate our focus on those parts that are common in the reverse logistics. In the collection phase, the volume and timing of returns from specific collection channels (retail stores, municipal waste collection centers, repair shops, etc.) may be affected by uncertain variables such as demand and customer behavior and failure rate. Since the quality of collected products may be effective in the way of assignment to the different reusing alternatives, it is supposed to determine their quality. Consequently, it may be required to evaluate product information (history of use or repair, technical specifications of product) or physical examination.

2.4.4.2 PDM Systems

Products Data Management Systems (PDM) focus on engineering aspects of product design and mostly is dealing with engineering data. The main activity of PDM systems is to safe storage of data in a controlled database. In many cases the main motivation to use PDM systems is coming from the time individuals encounter problems to find the latest documents and can't find them. In fact, product data management systems are a mechanism to connect objects and their characteristics. One of the main functions of PDM is supporting changes management, however, it is necessary to view a set of related objects as a single object under the changes management. Managing Different document formats is another capabilities of these systems. A PDM system should provide data saving in different formats; for example, a CAD tool can either be in only readable original format and also under editable format to be seen and printed.

- Tools for viewing objects and information.

- Integrating with other software

- Managing parts and suppliers

2.4.4.3 WMS systems

In direct logistics, warehouse management systems (WMS), the system performs administrative works and transportation supports. To support return processes, reverse logistics system or WMS are developed with proprietary systems for backward controls. Returns from retailers, supplier refusals, and packed returns in designated warehouses which are called “return centers”; are collected or gathered by distributed centers. Returns causes additional manpower and heavy processes in warehouses accounting for about six percent of total logistics costs. We hereby present 2 example of WMS. First one specifically is developed for returns transportation and the second one show a professional system.

Genco [81], has designed R-long as a RL program software which control returns and synchronize it with designated warehouse(return centers).in R-log, each product is assigned to a return center that is tagged by a barcode. In return center, the code is tracked by its unique number and routed to its container or warehouse. R-log offers an optimal recovery or an elimination option for returns based on available opportunities in the secondary market (sellers, scraps, and charities), costs and limitations such as returned product status, dangerous centers or special customer instructions. R-log connect to other information systems through a robust reporting mechanism, thereby facilitate returns financial controls, planning and production. R-log prepare qualitative and quantitative information for management (return reasons, returns from each seller, etc.). After determining optimal recovery or elimination channels, R-log will categorize similar products to reduce shipping and handling costs, and provide management control to verify proposed recovery or destruction activities. The number of manpower failures are reduced due to adopting radio frequency computers and bar code scanners.

Web-enabled applications for supporting reverse logistics operations are interfaces with to illustrate aspects of return uncertainty.

Effective control on volume of returns: often, the concept of control over the volume of returns is interpreted as reduction of input returns. Tracking and tracing orders helps to control direct logistics activities. Another alternative to reduction of returns is cross-examine from each order which is done to discover unconformity between items and to inform the customer; for example, when individual order is a color printer and spare cartridge which is not suitable for that printer, then, user interface identifies unconformity and inform the customer for confirmation.

Finally, factories set up choices and options for their returns on the web; meaning that, when customers have given their reasons for returning some of their products, they are redirected to a web interface (for example: www.Yantra.com, www.e-rma.com) which reduces customer returns due to some misunderstandings about the product function.

Minimizing uncertainty returns factors: The uncertainty about returns makes planning and managing difficult. Web interfaces are used to reduce uncertainty of returns; which means, when a customer declares a return, he is directed to a web interface that collects information about the product's conditions, in which the method of collection, time and place of returns will be selected. This gathered information provides the primary management for returns. In a more structured approach, a pilot experiment has been developed by Kokkinaki et al. (2002) [82], in which it is proved how the monitoring and benchmarking can reduce uncertainty about volume, type, and the quality condition of returns.

2.4.4.4 Eco-tools

Eco-Tools is an analytical tool that provides estimation of environmental factors of the production processes, options for recovery and disposal of end-of-life. Based on these estimations, eco-tools users, can test replacement design scenarios and choose the optimal design in terms of environmental factors and production cost.

Eco-tools receives input information about products such as: bill of material and sub-assemblies, with regard to labor-related rates, disposal rates, reusing and recovering cost benefits, unit weight of items, and disassembly sequences. Also, details of production, disassembly, end-of-life processes, and sub-assemblies are another inputs for eco-tools. Eco-tools by having life-cycles analysis tools (LCA) are differentiated from design for disassembly tools (DFX) and waste management tools (De Caluwe, 1997) [83] . LCA tools analyzes the products based on environmental behavior over the product life cycle. Generally, LCA tools are including following phases:

- objectives determination and limitations
- Inventory analysis
- Impact analysis
- Improvement analysis

In the first phase, users determine the product to be analyzed. During the product analysis, inputs (processes) and outputs (i.e., emissions, toxicity) are quantitated from product processes and activities are calculated for periods of their life cycle. In the impact analysis phase, the qualitative and quantitative outcomes of the past phase are implemented to calculate the product, either in direct effects (ozone depletion) and long-term loss (i.e., the risk of increasing health problems). Improvement step, which may not exist in any LCA tool, systematically assesses the opportunity to reduce the environmental impact over the entire life cycle for all product-related processes.

The requirement for large data in LCA tools raises important issues about their widespread use. One way to reduce these needs is to develop a mechanism for interactions of PDM systems or CAD / CAM with LCA tools in order to enable them to exploit product related information. On the other hand, using a simplified approximation methods, based on energy, toxicity parameters, and waste, will reduce information requirements for related parameters to LCA tools.

DFX is similar to LCA. DFX tools focus on improving product design which are related to production methods, fastening methods, and used materials. DFX tools mostly concentrate on end-of-life/ end-of-life stage. The purpose is to increase alternatives to revival of components through reuse or recovery. If it is not possible, DFX tools may help reducing the environmental burden resulting from burning or destroying. Waste management tools, receive Input information about product design, manufacturing materials and processes and provide alternatives to EOL options at different levels, taking into account time-dependent characteristics and backgrounds such as return quality, geographic information on returns, rules, and return prices in secondary markets.

2.4.4.5 ERP System

In this section we express about modules of enterprise resource planning (ERP) which support reverse logistics activities. If ERP systems integrate successfully, it will interconnect financial part, production, human resources, distribution, and order management systems within strong integrated system by information which are divided across the business environment horizontally. Well-known ERP systems are SAP R/3, Oracle ERP, and Siebel. Van Hillegersberg et al (2001) [84]has explained elaborately about how to use ERP in order to support different process domains. Here we focus on the use of ERP to support production and revival processes.

An important step to product recovery is disassembly. ERP system utilize returns to support disassembly scheduling in order to recycle cores. The cores disassembles to components and then they will be inspected and tested. The pieces whose qualitative standards are appropriate are stored for reuse. The pieces with small defects are firstly repaired then will be stored for reuse purposes. The rejected parts will be scraped. Disassembly process will show us requirement to additional information, including efficiency level of reusable components/repairable from disassembly process in addition to repairing part of repairable components. Which can be repaired from the assembly processes, plus the repair time of the components to be repaired. This information are recorded in recovery BOMs.

ERP Software packages do not support recovery/revival BOMs. Therefore, they need development to demonstrate the additional information requirements. In addition, ERP software packages for managing returns, needs new functionalities.

2.4.5 E-commerce models

In the research of Kokkinaki et al. (2002) [85] has been presented that how e- commerce provide RL integration and facilitate redistribution of returns to market. And based on this study, in this part briefly we describe the 3 e-commerce models.

2.4.5.1 Returns Aggregators

Specifically, e-commerce models for collecting returns bring together suppliers and customers, automate the procurement of returns and create value through high throughput and minimal transaction costs. A returns aggregator differs from consolidating returns channel (e.g. those specific returns channels which are directly managed and owned by the original manufacturer of the product like IBM's online exchange for computers and parts at: www-1.ibm.com/financing/gars/wb/ios/ioslogon.html.) in that they handle returns from many different OEMs[5], without owning products. There are returns aggregators for different returns flows, which are:

-Production waste (www.metalsite.com),

-commercial returns (www.qxl.com),

-End-of-use products (www.ebay.com), or

-their combination like www.180commerce.com).

Basically, returns aggregators do not control the returns, which are stored at their initial location, until a transaction is completed. Then, third party logistics operators (3PLOs) are responsible for transferring the returns to their destination.

Furthermore, a dynamic price-determining mechanism (often an e-auction) enables high throughput of transactions and the de-fragmentation of a highly fragmented market.

U.S. based returns aggregators such as www.ebay.com concentrate within the North American market, due to their geo-demographics or managerial decisions to simplify required logistics operations. However, In the EU, returns aggregators are country-oriented (www.viavia.nl), as they follow cultural, logistic, linguistic and financial diversities between different state members. For instance, www.qxl.com propose different content in its sites in some places such as France, Netherlands, Italy and Germany.

By implementing auctions to track the demand and set the price, returns aggregators can overcome difficulties associated with conventional means for managing returns. Particularly, returns aggregators offer high added value in markets, which have a large number of transactions with low individual transaction value. And finally, the added value of returns aggregators increases according to the number of different SKUs they handle, because that increases the critical mass of their potential clientele. Moreover, most returns aggregators are open to all buyers, whereas sellers have to register and pay fees.

2.4.5.2 Speciality locators

While returns aggregators reveal in mature markets, speciality locators are concentrated on niche markets. Speciality locators focus on highly specialized used parts or products. Such as

[5] Original Equipment Manufacturers

authentic antiques, exact replicas parts or equipment in historic restoration projects or the maintenance process for vehicles and industrial equipment.

The main characteristics of this model are: regional-bounded, and vertically structured, focusing on a limited range of used parts or equipment over a geographical region. Thus, the major asset in this model is the ability to provide specialized service. Provided services include training, methodology for catalogue search, selection and configuration, financing and technical support.

Due to highly prizes in this model, participation of suppliers in speciality locators is usually subject to financial contribution. This e-business model has high entry barriers; such as the need to design and impose new standards in a specialized topic, structure of information and market liquidity.

Obviously, Easy identification of the part or product requested is a central issue and as a competitive advantage to the success of a speciality locator. Standards and structure differ from one implementation (www.find-a-part.com). To another (www.bigmachines.com), whereas conventional catalogues of spare parts offer a unique coding system related to one supplier only. Identification of a part can be improved through special purpose web-accessible search engines which focus on some prominent features of the part such as brand, description, code etc.

Some speciality locators address the issue of preventive or reactive maintenance for heavy industrial equipment, which may operate in geographically remote places and under very hard conditions. Remanufacturing of industrial equipment is often a closed loop process, in the sense that users give in a piece of their equipment and sometime later they get it back remanufactured. Finally, this model is leading to more customization.

2.4.5.3 Integrated Solution Providers

The integrated solutions providers' model goes a further step beyond facilitating and matching demand and supply of returns. They capitalize on their distinctive expertise and use Web-based technology as an enabler to provide special services. Moreover, they actually become the owners of the returns instead of implementing a brokering mechanism as the previous two models. This model aims to create effective and long-term relationships with customers in industries where the cost of a return itself may not be high, but its speedy handling is essential to its core business process. This e-commerce model creates value through processing fees and locking in the customer for add-on services or products. In addition, each integrated solution provider concentrate on the reverse logistics network in an industry or a sector, which is, pharmaceuticals (www.returnlogistics.com , www.pharmacyreturns.com), machine tool manufacturers (www.milpro.com) or cellular phones (www.recelllular.com).

Return logistics providers has included in its web accessible databases around 80.000 product descriptions. By a search mechanism, users specify their returns and choose a disposition method (return to OEM, disposal, sell, exchange or donation). Furthermore, it helps users with the suitable packaging and shipping documentation. Finally, it provides the full range of logistics services including disposal of controlled substances, repackaging, and de-packaging of products/parts.

The model for Integrated Solution Providers is still in its infancy phase, probably because it does not view E-commerce as a migration of existing practices and services over a new infrastructure, but, instead, as a new tool to restructure a business activity and offer new services.

2.5 New IT technologies in closed-loop supply chain

2.5.1 RFID technology

The main idea behind RFID is a microchip placed on a pallet or other objects, and information on the chip can be read by a RFID receiver. RFID is a newer technology than the bar codes which read information from laser frequencies. It is more effective than barcode in case of tracing objects in an environment where barcode labels are not very suitable or cannot be used as a data collector in the straight line or where information is required to be automatically updated. RFID is based on Wireless systems (radio), which by reading data from non-contact objects, provide accurate and timely data from production flow in manufacturers, stores, warehouses, retailers, and suppliers. In this system, tags are attached to objects. Each tag has a built-in (internal) memory that stores specific information about product, suppliers and other related information in itself such as a unique electronic product code (EPC).

Generally, RFID tags have more benefits than barcodes such as:

- It's not necessary to be directly in front of the reader to be read

- Tags can be read at the same time

- Typically they can store more information than barcodes

- reading information can be completely automated (without need to operator)

- Data accuracy is very high

- Identification of objects is done individually, while the barcodes only identifies the class of the objects

- Tagged objects can be automatically counted

- Writable/readable tags can be updated with new information on the product life cycle (they are editable)

Figure 2-6 displays how RFID works systematically. As it is obvious different tags in order to facilitate the process of saving data, controlling, counting, and managing the product information are used such as individual tags on the products, boxes and pallets aggregate tags and containers tags. Then, when the transportation is done in the new destiny, product information can be read by readers. After that, these information are sent to local server of the organization. And finally they will be added and integrated by the whole enterprise database systems such as ERP, SCM, and CRM.

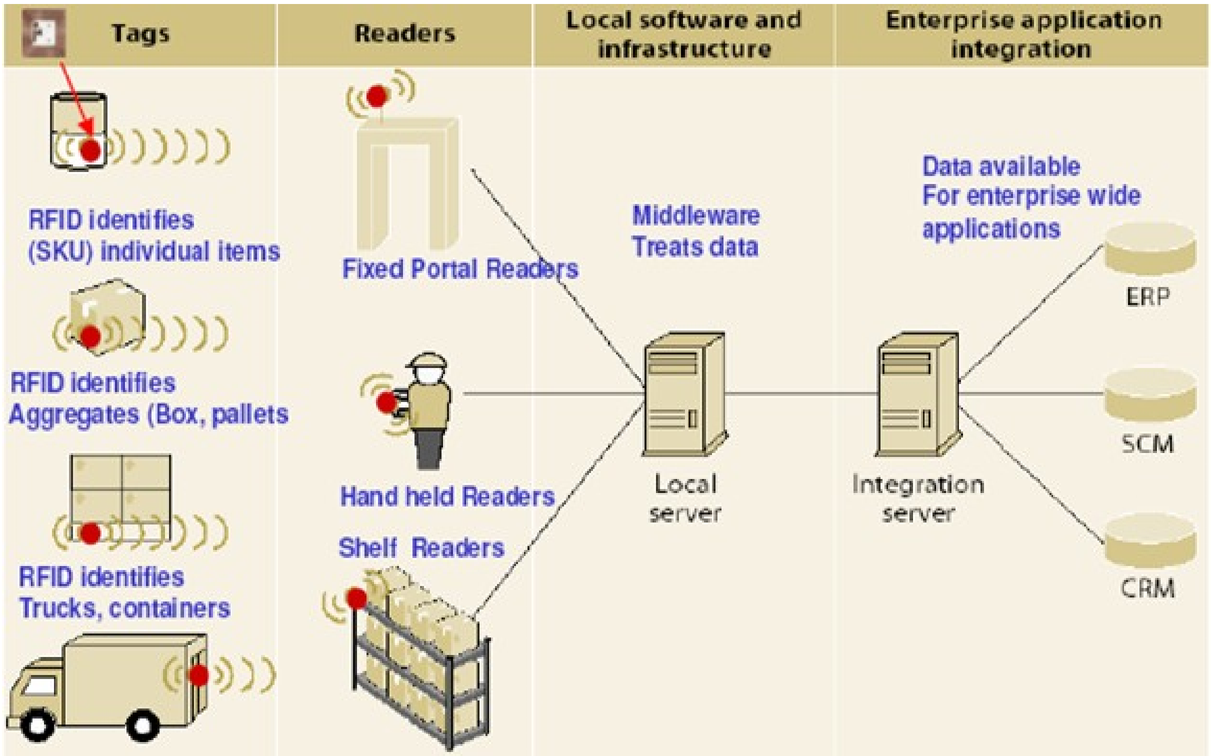

Figure 2-6: RFID function

RFID technologies are categorized into passive RFID, active RFID, and semi passive RFID [86]. According to radio frequency used, the passive RFID technologies usually operate in low frequency (LF) RFID, high frequency (HF) RFID, ultra high frequency (UHF) RFID, while active RFID operate in ultra-high frequency (UHF) band. Furthermore, in active RFID systems, tags have their own transmitter and power source and usually, the power source is a battery. Also, active tags broadcast their signal to transmit the information stored on their microchips. While, in passive RFID systems the reader and reader antenna send a radio signal to the tag. The RFID tag then uses the transmitted signal to power on, and reflect energy back to the reader [87].

RFID has many applications in various fields, including security systems, warehouse control systems, library document recognition systems, administrative systems and pharmaceuticals, hospital systems, and so on. One of the most important applications of RFID, which has become popular today, is its use in the integration of supply chain systems. Although this technology is still at the top of the way, managers have a lot of concerns about the return on investment, enhancement of their system efficiency, and the risks of this technology. However, there are some successful experience of using RFID technology (like Walmart Company).

2.5.2 Applications of RFID technology

Nowadays, RFID has implemented in different domains and industries. For instance, in 2005, Wal-Mart Company (e.g. a U.S. public corporation which runs a chain of large discount department stores) obliged its most important suppliers (more than 100) to placing of tags in all shipments in order to improve the inventory management. Consequently, the company managed to reduce stockouts by 16% by the use of RFID technology [88]. This decision increased waves of RFID usages in different industries.

The application of RFID technology in manufacturing industries mostly is limited to specific activities and can be benefited by RFID in product tracking, collection of new data encountered during the production process, and the provision of parameters required for quality control. To benefit more of RFID technology, it is essential to extend the cooperation with logistics and warehouses. So, we can use tags for carrying information from production to warehousing and logistics to facilitate their business. In addition, storage optimization in warehouses and easier transport programming, thanks to a more detailed and precise information provided by RFID, is achievable in real time. The retail industry also benefit from RFID technology [89]. RFID can be implemented in libraries to simplify the process of borrowing and returning books. Then, as a result, they mentioned that the rates of errors and thefts decrease [90] .

Moreover, there are specific levels in processed food supply chains where significant exposure to risk exists [91]. In fact, approaches such as control at critical points of the process, hazard analysis and employee training program exist to prevent risk. In case of happening corruption such as recall, the use of RFID ensures that only items from specific production lines will be withdrawn instead of the whole production.

Fashion Product development also implement RFID technology in management system [92]. The management of end-of-life products with RFID is taken into account in studies of Parlikad and McFarlane, 2007 [93]. In their research, due to the fact that many product information will be lost after the point of sale, they showed how radio-frequency identification (RFID)-based product identification technologies can be employed to provide the necessary information and preventing losing data.

2.5.3 Blockchain technology

2.5.3.1 What is Blockchain technology

Blockchain technology is a decentralized distributed ledger which records transactions through a protocol between two parties in a verifiable, trustworthy and permanent way [94]. The blockchain, or which was originally called as block chain, is a list of records referred to as blocks. And these blocks are linked together and secured by cryptography. Each block in the chain is linked to a previous block with a hash pointer [95]. In addition, there is also a time stamp for each transaction in the chain and a nonce which is a random number for verifying the hash [96]. This sequence of blocks continue until the genesis block which is the first block in the chain. The blockchain technology by using a consensus mechanism (see section 2.5.3.4) which is the process in which a majority of network validators come to agreement on the state of a ledger [97] ensures the integrity of every block or record by recording the transactions across a network of computers. In this way, no record of transactions can be altered or modified without changing the other blocks. In order to add a block in the chain, the majority of nodes in the network must agree on by a consensus mechanism on the validity of transactions in a block and on the validity of the block itself. In Figure 2-7 a schematic view of such chain is shown [98]. Blockchain technology is different from many existing information systems designs by including four specific key characteristics; decentralization, security, auditability, and smart execution [99].meaning that It deals with confidentiality, uniqueness, and security of information.

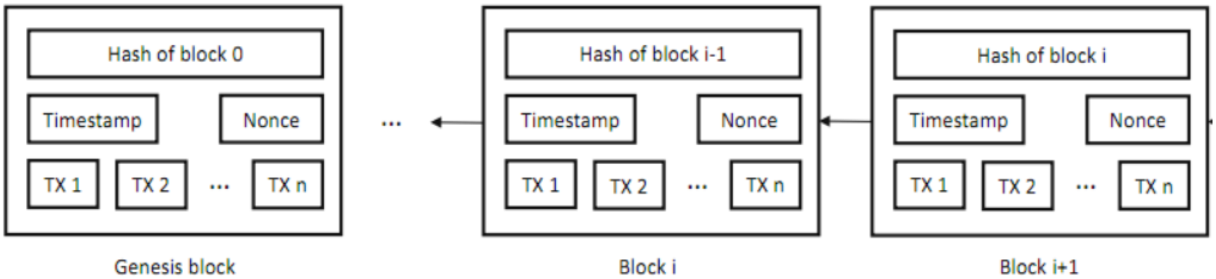

Figure 2-7: chain of block components in blockchain

Here is a brief explanation of how a blockchain technology works based on following steps:

Step 1: one party request a transaction in the network

Step 2: requested transactions are funneled into a peer-to-peer network and broadcasted to all other members of the block networks (nodes)

Step3: nodes receive the request and validate the transaction using an algorithm (e.g. by creating a hash from processing original data)

Step4: approved transactions are represented as blocks and added to a public distributed ledger

Step5: after adding the block to an existing chain, transactions are complete and permanent.

2.5.3.2 Centralized vs. decentralized ledger

In comparison to centralized transaction systems (centralized ledger) to store and validate the data, blockchain uses a decentralized transaction system (decentralized ledger) to store and validate the data in which any actor can reach, and have access to the historic log of the system. In this way, reaching to transparency is easier. In Figure 2-8 these concept are illustrated. The concept of a distributed ledger means that any changing to the ledger should be shared with and synchronized across the entire network. For example, if X makes a change to the ledger, the said alteration will automatically appear on Y's ledger, in case they belong to the same blockchain. Consequently, other users of the blockchain in the network will see the said change. It worth noting that the users in a blockchain do not view separate ledgers from each another. Instead, the whole blockchain network uses a single distributed ledger, and all alterations are made and spread across the network instantly in real time.

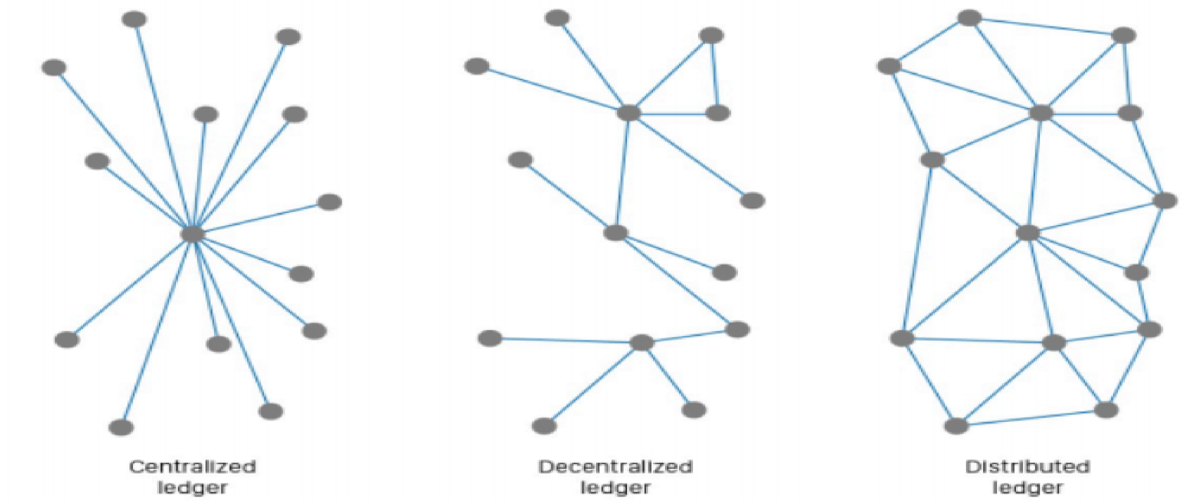

Figure 2-8: different type of ledgers

The implementation of such decentralized technology in several fields (going from public to private sectors) where higher levels of privacy were required, led to a further classification: the permissionless ledger and permission ledger. In following section these concepts are explained.

2.5.3.3 Blockchain system architecture

Blockchain networks are typically consist of 2 parts: users and validators. User nodes are able to initiate or receive transactions and keep a copy of the ledger. While validators, mostly are known as miners, are responsible for approving modifications of the ledger and reaching consensus within the network. All Internet users are able to join a public blockchain system. But in private blockchains systems the access is restricted and limited only to authorized participants. By considering ledgers, permissionless ledgers are completely distributed and as any member of the network can participate to the validation process of transactions. On the contrary, with permissioned ledgers only a certain number of validator nodes keep write access rights to modify the blockchain network [100]. With public and permissionless ledgers, users and validators in the network are entirely unknown to each other, so to reach a consensus, the collaborative effort is required for ledger management which is mainly based on rewards. The structure of incentives are affected by spending resources such as computational work, and electricity that aims to deter selfish action [101]. With private and permissioned ledgers, the users and validators are known to each other. In such system, validator nodes are known and trusted to behave honestly through the network. Consequently, because of having limited access and more privacy, private and permissioned ledgers are quicker, more flexible and efficient. However, this causes the expense of immutability [102]. In addition, some ledgers can be classified as consortium blockchain ledgers (i.e. hybrids which stand between public and private blockchains) [103]. The comparison between public, private, and consortium blockchain are mentioned in Table 2-4 [104].

Table 2-4: comparison between public, private, and consortium blockchain

Property	Public blockchain	Consortium blockchain	Private blockchain
Consensus determination	All miners	Selected set of nodes	One organization
Read permission	Public	Could be public or restricted	Could be public or restricted
Immutability	Nearly impossible to tamper	Could be tampered	Could be tampered
Efficiency	Low	High	High
Consensus process	Permissionless	Permissioned	Permissioned

Consensus determination: In public blockchain, each node could participate in the consensus process. But in consortium blockchain only a selected set of nodes are responsible for validating the block in. while in private chain, it is completely controlled by one entity and the organization could specify the final consensus.

Read permission: Transactions in a public blockchain are visible to the public while in private blockchain or a consortium blockchain it can be visible to all or limited.

Immutability: Since records are stored on a large number of participants in the network, it is almost impossible to tamper and change transactions in a public blockchain. Unlikely to this, transactions in a private or consortium blockchain could be tampered easier than public blockchain due to the existence of limited number of participants.

Efficiency: public blockchain network due to being open to ever participant, there are a large number of nodes. As a result, transaction in order to be done take more time. But consortium blockchain and private blockchain with fewer validators could be more efficient.

Consensus process: since there is no limit of participating in consensus process of the public blockchain, it is permossionless. While, both consortium blockchain and private blockchain are permissioned.

2.5.3.4 Consensus algorithms mechanism

Consensus mechanism is the process in which a majority of network validators come to agreement on the state of a ledger [97]. Subsequently, new blocks in order to be added to the chain and accepted between members need to be mutually agreed and validated through consensus algorithms. The methodology applied to reach consensus in blockchain networks depends on many key performance characteristics such as scalability, transaction speed, transaction finality (i.e. required time for the block, depending on the consensus algorithm used, to become a permanent part of the blockchain), security and spending of resources such as electricity [105]. Many approaches for the consensus procedure have been suggested. Some scholars broadly classify these as lottery-based and voting-based [105] [106]. Lottery-based approaches include proof of work

(PoW) public blockchains, which is currently used by most cryptocurrency systems such as Bitcoin and Ethereum. In PoW systems, the algorithm rewards participants who solve computationally-intensive mathematical (cryptographic) puzzles in order to validate transactions and generate new blocks. Another alternative to perform consensus process, are proof of stake systems (POS), in which validators are opted either at random or within a round mechanism, but the power of the 'vote' of each validator depends on the size of its 'stake' in the system , for instance, as the amount of cryptocurrency kept in deposit or in another commodity. Voting-based approaches include those based on the Practical Byzantine Fault Tolerance (PBFT) algorithm. In BFT, nodes send votes for blocks to accept within a replicated (multi round) process, then, at the end of which validators agree on whether to accept a block as a permanent part of the chain. However, sometimes happens that the votes are transferred through a potentially unreliable network and some of the validators may be untrustworthy. Therefore, the consensus voting process needs careful design.

In following section, we elaborate and explain the most important consensus mechanism which was already mentioned.

2.5.3.4.1 Proof of work (POW)

The first evidence of using POW was found in the 'Hashcash' proof of work developed to limit denial of service attacks on Internet resources and mainly was utilized by bitcoin [107]. Miners (validators) compete with each other to add a new block in the current blockchain by solving a cryptographical puzzle. This method adds a nonce and calculates the hash output of the block header (i.e. the block header contains information such as the hash of the previous block validated) and merkle tree (i.e. a specific hash of all transactions contained in the block). The aim of all miners is to achieve a hash output which is lower than a specified target. The only feasible way for miners to predict or influence the outcome is that of trial and error. This procedure requires computational effort which grows exponentially with the number of trailing zeros. When a correct hash output is identified, the block is returned to the bitcoin network and is accepted by other nodes in the chain if all transactions are valid, and finally the successful miner gets a financial reward.

All succeeding blocks contain hash outputs from all previous blocks. Specifically, Bitcoin mining based on the computing power of standard computers, therefore, anyone could become a miner in the chain. Since 2014 mining has been bounded by specially designed computer chips, called as application specific integrated circuits (ASICs) [108]. Miners have gradually joined coalition pools in order to leverage risks and to maximize returns. Consequently, mining power is increasingly turning more centralized in cartels or 'mining pools'. This has initiated a direction of research which uses some techniques from game theory and mechanism design to discourage centralized cartels from forming and decrease their impact on the Bitcoin system [109].

PoW strategies have shown that they can scale up to a large number of users, however, transaction rates and finality may not be suitable for some use cases [110]. For instance, the original version of Bitcoin can process approximately 7 transactions per second [111], 1 block every 10 min and may need on average up to 1 hour to reach 'finality'. It should be noted that in practice confirmation time may be different as block generation is not deterministic. In practice, confirmation time depends on the amount of network activity and transaction fees. A number of confirmations accepted by the majority of the Bitcoin community and wallet providers is 6 confirmations. And this confirmation process takes about 1 hour for the block to get accepted [112]. Early blockchains developed in the Ethereum platform which use PoW is able to deal a maximum of 20 transactions per second [113]. While Visa is able to support up to 24,000 transactions per second. Solutions to these issues in the blockchain systems are being investigated such as increasing the block size [108] or pruning [114].

A main disadvantage of PoW mechanism is that it wastes a large amounts of real resources such as electricity. For example, Ethereum's Wiki pages express that Bitcoin and Ethereum platform burn more than $1 million worth of electricity and hardware costs per day for running their consensus mechanism [115]. Pilkington [110] shows that Bitcoin could potentially one day consume up to 60% of global electricity production, equivalent to 13,000 TWh powering 1.5 billion homes. Some other sources claim that Bitcoin could consume as much electricity as Denmark [116] by 2020, with validation of one single Bitcoin transaction currently wasting 200 kWh of electricity [117]. This cost may not be justified and reasonable. To solve these issues another alternatives have been suggested, such as proof of stake.

2.5.3.4.2 Proof of Stake (PoS)

Proof of stake (PoS) was introduced as a solution to solve the problems of proof of work. PoS replaces computational work with a random selection mechanism, where the chance of successful mining is related to the wealth of validators. This approach can potentially leads to faster blockchains [110] that uses much lower electricity consumption in comparison with POW and a reduced likelihood of a 51% attack [115]. Furthermore, it doesn't need to constantly generate new coins to incentivize validation. Instead, miners' rewards are based only on transaction fees and can't achieve greater gains by investing in hardware equipment, such as ASICs. PoS can benefit from game-theoretical mechanism design to prevent collusions and centralization, by often penalizing dishonest and malicious behavior. The main vulnerability/disadvantage of PoS systems is identified as the 'nothing at stake' problem or in other words, claiming financial rewards for multiple chains is cheap. Some alternatives have been proposed such as integrating a punishment mechanism for validators which simultaneously produce blocks in multiple chains and automatically deducting coins owned or deposited. Another alternative is punishing validators for generating blocks on the wrong chain, similarly to PoW, where also validators causes the cost of electricity. PoS-based algorithms can be used in public blockchains, or in private-oriented settings, where validators form a known set of trusted entities [115].Ethereum, is planning to move from PoW to PoS solutions. In trusted or semi-trusted environment conditions, voting-based algorithms such as Practical Byzantine Fault Tolerance (PBFT) is able to provide adequate solutions. PBFT is introduced in the following section.

2.5.3.4.3 Practical Byzantine Fault Tolerance (PBFT)

Byzantine Fault Tolerance (BFT) algorithms was initiated based on the work on Byzantine faults, and firstly characterized by Lamport et al. in a seminal computer science paper [118]. Briefly describing, the problem relates to a set of Byzantine generals (equivalent to the nodes in a blockchain setting), agreeing on a joint unify plan of action. For the Byzantine generals, the joint action requires coordinating between different parts of an army to attack a fortress simultaneously (equivalent to reaching consensus on whether to validate a block). The challenge is that messages in order to be transferred between the generals have to pass inside enemy territory/land and may be lost without notification/identification of either sender/receiver (i.e. in blockchain term correspond to travel in an unreliable, distributed network). In addition, some of the generals may be traitors and interested in passing messages that sabotage the battle plan, by sending incorrect or distorted messages, or not responding to messages at all. The main challenge is, how to ensure that loyal generals can reach consensus on the attack plan, and also a small number of traitors should not cause them to implement a wrong plan. In the blockchains terminology, it means that a small number of untrusted or potentially malicious nodes should not be able to cause the validation of a bad block. Studies of Lamport et al. [118] shows that guarantees can be provided if it is no more than 1/3 of the total number. The PBFT algorithm proposes multi-round check mainly primary and secondary replicas, where the secondary replicas check the correctness of the primary and can switch to a new primary if the previous one is compromised.

In PBFT algorithm Transactions are individually verified and signed by known validator nodes, to make PBFT more suitable for implementation with trusted environments instead of public permissionless ledger applications. Transactions in PBFT are considered valid and consensus is reached when an adequate amount of signatures is collected. The algorithm needs at least 66% (2/3) of the network to behave honestly and messages overhead may increase as the size of the network grows, impacting on speed and scalability [119]. Many different of BFT-based protocols have been suggested by developers, such as Hyperledger, the open-based platform supported by the Linux Foundation [120].

2.5.3.5 Comparison between POW, POS, BFT

In this section we demonstrate a comparison of the main consensus model categories that we discussed so far in this document. Table 2-5 summarizes the findings, which are more elaborated in this section [121].

Table 2-5: comparison between POW, POS, BFT

	POW	**POS**	**BFT**
Blockchain type	Permissionless	Both	Permissioned
Transaction finality	Probabilistic	Probabilistic	Immediate
Transaction rate	Low	High	High
Cost of participation	Yes	Yes	No
Scalability of peer network	High	High	Low
Trust model	Untrusted	Untrusted	Semi-trusted

Blockchain type: Blockchain type shows the type of blockchain platform based on the implementation of consensus model to whether permissioned or permissionless (see section 2.5.3.3).

Transaction finality: Transaction finality indicates whether the done transaction which added to the block has become the permanent part of the chain to be considered final. PoW carry the risk of multiple blocks being mined at the same time because of their model of leader election. Since this eventually leads to generating temporary forks in the blockchain and ends up the rejection of confirmed transaction. This leads to a probabilistic transaction finality model where clients will have to wait more for transactions to be considered as confirmed and finalized. While with the immediate finality, when the transaction is embedded in the block, it is confirmed and will not be rolled back.

Transaction rate: obviously, the faster to reach consensus, leads to higher transaction rate. PoW approaches are probabilistic and have to spend significant amount of time in order to solve cryptographic puzzle. Therefore it leads to low transaction rate. While BFT based approaches, PBFT and PoS are able to confirm transactions faster and are supposed to support higher transaction rates.

Cost of participation: PoW and PoS in order to execute the consensus algorithm needs participation which leads to inherent cost. PoW requires expending energy to run consensus protocol. While PoS needs nodes to buy some initial cryptocurrency in order to make a security deposit for declaring interest and bonding with the platform.

Scalability of peer network: Scalability of the consensus models is its ability to reach consensus when number of peering nodes are growing in the chain. POW, and POS have high scalability. While, BFT has low scalability. For BFT it is recommended to keep the number of peers in consensus network less than 20. Since increasing the number of peers more than 20 causes an increase in the number of messages sent and transferred between them which leads to a huge amount of overhead.

Trust model: Trust model indicate if the nodes participating in the consensus process have to be known or trusted. In PoW, and PoS nodes can be untrusted since the mechanism to reach consensus is based on computational work or security deposits. While in BFT, peering nodes must be known and registered with the system to be engaged in consensus process.

2.5.3.6 Suitable conditions to use blockchain technology

Generally, implementing blockchain only makes sense in conditions that multiple mutually mistrusting entities are going to interact with each other based on a trusted environment and are not willing to agree on an online trusted third party. If there is no need to store data, then no database is needed (i.e. a blockchain, as a form of database, is of no use). Similarly, if there is just one writer, (i.e. a writer in blockchain terminology means an entity with write access in a database system or to consensus participant process in a blockchain system) a blockchain does not provide additional guarantees and in this condition a regular database is better suited, since it provides better performance in terms of throughput and latency. If a trusted third party (TTP) is available, there are two options to apply: First, if the TTP is always online, write operations can be assigned to it and it can perform as validator for state transitions. Second, if the TTP is usually offline, it can perform as a certificate authority in the setting of a permissioned blockchain (i.e. where all writers of the system are known in the network). If the writers all trust each other (i.e. assuming that no participant is malicious in the chain, a database with shared write access is likely the best solution). But, if they do not trust each other, running a permissioned blockchain system makes sense. Depending on whether public verifiability (i.e. allows every member of the network to verify and observe the correctness of the state of the system) is required, anyone is allowed to read the state (equivalent to meaning of public permissioned blockchain) or the set of readers may also be bounded (equivalent to private permissioned blockchain). Finally, if the set of writers is unknown to the members, a permissionless blockchain is a suitable solution. In Figure 2-9 these decision making process is illustrated [122].

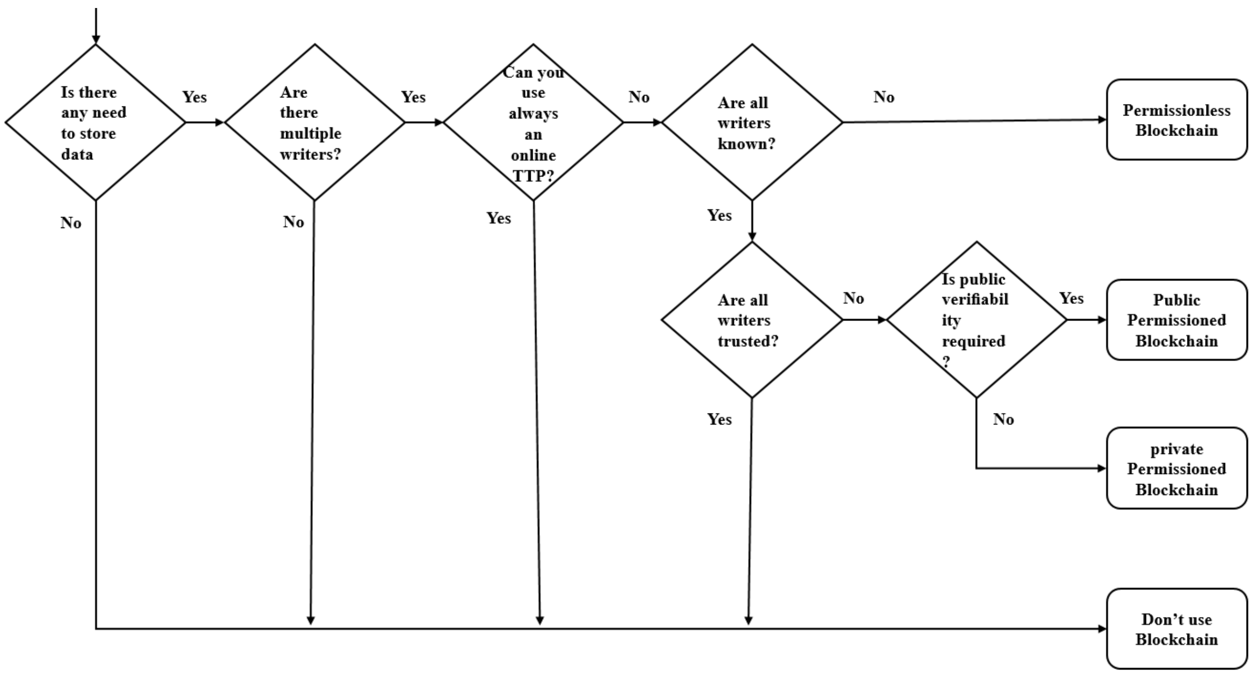

Figure 2-9: decision process to use blockchain

2.5.3.7 Smart contract

A smart contract term was firstly introduced by Nick Szabo. (1997) [123] when he says "*smart property might be created by embedding smart contracts in physical objects*". But, particularly, the utilization of such contract has been recently done due to advances in technology. The prominent of such implementation are Ripple's Codius[6] and Ethereum[7] which are projects based on blockchain technology. Smart contracts contain computer programming codes that are present in a network of blocks. It defines conditions, and when these conditions are met, all the computers in a network automatically validate and execute the conditions and contract. This guarantees the users to get the intended outcome.

Typically, the main motivation of using smart contracts comes from trust among members. Assume that one party want to ship some products to another party. But, the receiver of the product doesn't trust the sender in order to pay money before receiving that item. On the other hand, sender

[6] For further information: https://ripple.com/
[7] For further information: https://ethereum.org/

doesn't trust to receiver in order to be paid after delivering the item. To solve the problem, smart contracts are activated to ensure the transaction among parties and act as a third party. Therefore, Instead of sending the payment to the sender, receiver simply has to pay the shipment to a smart contract on the day of loading. Then, the smart contract will then hold the said payment until the receiver confirms the delivery of the item. After delivery and upon confirmation, the money paid by receiver will then be immediately released to sender.

2.5.3.8 The concept of the 51% attack in the blockchain

The 51% attack is related to the security of the blockchain technology. It means that for an attack against the blockchain to be succeeded, it must have at least 51% of the total hash rate of the blockchain network to be attacked or hacked. However, the 51% concept does not mean that a blockchain cannot be attacked. Consequently, an attack against a blockchain with less than 51% hash rate is still possible. However, such attack may have no chance of succeeding. In addition, an attack with more than 51% hash rate does not guarantee the success of the mentioned attack.

2.5.3.9 Advantages and disadvantages of implementing blockchain

The blockchain technology has its own advantages and disadvantages just like any other emerging technologies. So, here, we mention them briefly like following:

2.5.3.9.1 Advantages

High integrity*:* Blockchain Network users can be confident that the process will be executed in accordance with the blockchain protocol. Once a transaction is confirmed, literally, there is no way to change, or modify it. Therefore, there is no worry about any intervention that a third party might make.

Trustless: It means that no trust is required for the execution of transactions. Because, there is no intermediary involved thanks to the utilization of smart contracts to execute the agreement automatically.

Trusted data/reliable database/security: Blockchain technology guarantee that the data transmitted through its network is trusted and reliable. In addition, the data will always be complete, accurate, openness, and timely. Therefore, due to 51% attack meaning, tampering with database by one node is almost impossible.

Fair transparency: Thanks to the decentralized distributed ledgers, any data or information is viewable to the public. This leads to transparency, visibility, and fairness in the network chain.

More simplified version: Rather than looking at different ledgers, all the transactions accomplished over the blockchain, are added to a single ledger. Hence, it reduce the concern and time to monitor and analyze different ledgers at the same time.

Decentralization: There is no centralized organization in the whole network, and even if a node is crashed or damaged, the whole system will still work. Therefore, the blockchain system is very robust, stable, and decentralized.

2.5.3.9.2 Disadvantages

New technology: Although the blockchain is revolutionizing the world, it is fairly a new technology. It is not yet perfect. However, this technology aims to overcome so many problematic aspects, such as verification process, speed of transaction, and limitation on storing the data. Unfortunately, due to being in its early stages of development, there is a risk of failure to sustain itself in the long term.

Security risk: It is right that blockchain technology contain high security to the system which make it invulnerable to attack, however, it doesn't mean that there is 100% guarantee that is totally risk-free. There are many hackers out which are developing their knowledge and skills. Another security risk issue is that since the blocks are linked to one another, a single bug if penetrate in the blockchain network can impose a serious threat to the entire network.

Lack of trust: Unfortunately, although one of the main advantages of blockchain technology is its high security and integrity, many people/companies don't trust it due to inadequate knowledge about blockchain. So, they ignore to apply it and rather than studying it, they simply dismiss the idea behind it and continue sticking to the traditional practices.

2.5.3.10 Blockchain Applications - from Managerial approach

From a managerial perspective, to create value through blockchain it is necessary to embed it in some practical applications. The first and initial application of blockchain was Bitcoin, a financial platform which enables bilateral financial transaction. Even if the most of the applications of blockchain are now devoted to the financial sector, blockchain has more potential to revolutionize industries. As an emerging technology which enable safe and trustable transactions between unknown parties, blockchain applications are increasing their necessity in supply chain and tracking processes. Many of the applications created in the recent years in all the sectors are based on permissioned blockchain platform, like Hyperledger [124] . In Table 2-6, based on 185 services, the applicability of blockchain in different sectors is identified [125].

Table 2-6: blockchain application in different sectors

	Processes								
Sectors	Data & Document management	Property transaction	Capital markets	Payment	Supply chain finance	Tracking & Supply chain	Identity	Voting	Marketing
Agri-food						8			
Automotive	2								
Finance	12		35	48	11	8	6	5	
Government	4	4					5		
Healthcare	4								
Insurance	2			1					
Logistic	1					8			
Luxury						1			
Media									2
Utility	1			1		6			
Other	6					1			3

2.5.3.11 Blockchain technology and closed-loop supply chain

Blockchain technology as immutable, distributed, transparent, and trustworthy databases, shared by a community, has the potentiality to influence closed-loop supply chain networks. Tracking potential social and environmental conditions which might cause environmental, health and safety concerns is an important application focus for the blockchain [126]. A blockchain-based supply chain provides better conditions to prevent abusing of human rights and fair work practices. For example, a transparent record of product history assures buyers that purchased goods have been supplied and manufactured from sources which have been verified as being ethically sound. Smart contracts especially have a great capability for rules of tracking and controlling sustainable terms and policy conditions autonomously and governing appropriate corrections and sets.

Closed-loop supply chains have achieved significant interest amongst scholars and practitioners [127]. Not only from a business perspective of the supply chain it is important for circular supply chains, but also expanding the focus to environmental and social dimensions has made the attention to a more generalizable and holistic perspective on the supply chain. Blockchain technology is able to support data collection, storage, and management product journey, supporting significant product and supply chain information. As a result, transparency, neutrality, reliability, and security for all supply chain members and customers can exist in this technological context [4]. The food and beverage industry have more pressures to obey supply chain sustainably. An interesting technology in this context to support the condition is Radio Frequency Identification (RFID) and blockchain technology together to equip a food supply chain with traceability system for actual-time food tracing based on Hazard Analysis and Critical Control Points (HACCP) rules [5]. It is able to record and store supply chain events in the agricultural sector [128]. Blockchain can help supply chains to identify unethical suppliers and counterfeit products because all the information can only be recorded and stored by authorized members of the chain.

Implementing blockchain technology can benefit a company and its supply chain from different business perspectives affecting their economic performance. Blockchains can result in supply chain disintermediation where fewer tiers of the supply chain result in transaction costs and time reduction, and decreasing business waste in the supply chain [129]. This technology can share quickly every modification of the data, permitting for rapid deployment of products and processes and at the same time, minimizing human errors and transaction times. In addition, Blockchain technology can guarantee the safety and authenticity of the data, which will causes the reduction of the cost of preventing data from deliberate and capricious alteration enhancing supply chain risks and reducing business reliability [130]. Besides this, customers and governments now request for transparency within supply chain. Pioneering companies believe the competitive advantage of transparency in their business area [129], which leads to increasing customers' trust to purchase more products and services from our company and consequently benefit the firm financially.

Environmentally, blockchain technology has the potentiality to aid supply chain networks from many different perspective applications. Firstly, tracking substandard products correctly and identifying more transactions of the products results in helping reduction of the rework and recall of products, which aid to decrease resource consumption and reducing greenhouse gas emissions.

Beside, traditional energy systems are centralized while a peer-to-peer blockchain based network technology can decrease the need to transmit electricity over long distances and as a result it saves a big portion of energy wasted over long distance transmission. It also decrease the need for energy storage which saves its resources. There are some power platforms based on blockchain technology to decrease the waste of the supply chain, such as ElectricChain, and Suncontract [131]. Secondly, blockchains could be used to guarantee that green products are environmentally friendly. The processing information for green products is often unavailable and hard to verify. If the manufacturing process of a product is verified and certified concisely to be green in terms of greenhouse gas emissions level, environmentally conscious customers will have more interest to buy green products. For example, Ikea Company has a desk product produced from wood cut in a sustainable Indonesian forest. So, Ikea have to follow the wood from the time it is cut through manufacturing to the final product to assure the desks really made from that exact wood. Undoubtedly, this process is complex but can be managed with the help of blockchain technology. One example of the context is the Endorsement of the Forestry Certification programme which traces the provenance of approximately 740 million acres of certified forests from all over the world adopting blockchain technology [132]. Thirdly, blockchain can improve the recycling. People and companies may not be motivated to take part in recycling programmes. Blockchain technology has been adopted to motivate people in Northern Europe by financial rewards in the form of cryptographic tokens, in exchange for collecting and depositing recyclables like plastic containers, cans, or bottles. Meanwhile, it is hard to track, evaluate, and compare the impact level of various recycling programmes. Blockchain makes it possible to track data in order to evaluate the impact of different environmentally friendly programmes. As an example, Social Plastic is an innovative project based on blockchain technology to turn plastic into money and the aim is to reduce the plastic waste. RecycleToCoin is another blockchain application example which enables people to return plastic containers [131]. Thus, the possibilities for this kind of efforts within closed-loop supply chains area make blockchain helpful to emerge and highlight some concepts such as the circular economy. Fourthly, blockchain benefits the emission trading process by developing emission trading schemes (ETS) efficacy. By using blockchain technology, fraud can be avoided due to transparency nature of blockchain. Therefore, a reputation-based system is created which is able to solve the inefficiency of ETS and it encourages all the participant to figure out a long-run solution to the emission reduction, because the network members are encouraged by the economic benefits of good reputation [133].

3 Research methods (Methodology)

By considering the functionality and potentiality of blockchain technology and RFID in supply chain management, I am going to point out the potentiality of these emerging technologies together not just for forward/direct logistics, which have received some attentions by other researchers, but also the applicability of them in reverse logistics area. Therefore, in this way we can integrate forward and reverse cycles in supply chain that we define this integration as closed-loop supply chain.

To reach the purpose, firstly I used different research resources and materials such as different academic journals, companies' websites, Google Scholar, and Youtube channels in order to increase my knowledge about the topic. During this phase I used different relevant keywords and their combinations to enhance my insight which are: *supply chain management, forward logistics, reverse logistics, RFID, blockchain technology, block chain, smart contracts, transparency, counterfeiting, information technology, decentralization, confidentiality, traceability, and closed-loop supply chain*. In addition, during the selection of relevant research studies, the purpose of the thesis, research gaps, and research questions were taken into consideration. It should be noted that due to the fact that just few companies so far in the world have utilized blockchain technology in their supply chain networks and mostly they are working on pilot projects to examine and test the results. So, no real data is available to be considered for improving the quality of this research.

Consequently, based on my researches and after deeply understanding of the issue in direct logistics cycle, I am going to extend the usability of the combination of blockchain and RFID technology together in reverse logistics also. Then, discussing the prerequisite conditions, required data coming from forward logistics, and new data which must be embedded in product profile to make it integrated for the whole supply chain. After that, by mentioning 2 different scenarios based on the type of reverse logistics operations for returns I conduct the development of the model. And finally the advantages and disadvantages of such system is demonstrated. Moreover, it worth noting that in order to present it practically, I am going to introduce one example of the applicability of it in closed-loop supply chain.

4 Analysis and results

4.1 Introduction

In this section, firstly we will demonstrate starting point of the proposed system by studies of Abeyratne et al (2016) [134] but making some modification in its model mostly on product profile in forward logistics, and then we develop it for reverse logistics. Secondly, by one example we illustrate the information journey of products through the whole supply chain within our new traceability system. Thirdly, we express the advantages, disadvantages, and challenges coming from this new decentralized system. It should be noted that for the sake of simplicity, we assume our closed-loop supply chain based on Figure 2-3 in section (2-3-7).

4.2 Forward logistics network platform

As it was already mentioned, the proposed approach is built based on decentralized distributed system which uses a combination of blockchain and RFID technology to collect, store, share, notify, and manage key product information of each product throughout its life cycle in each entity of the supply chain and also notify all of network entity members about the transactions. Each of the network members (entities) have an active role in the system and have to update the current status of the product by logging in the blockchain network. Therefore, thanks to RFID readers in different entities the required information are updated and added by entities in the distributed ledger of the blockchain in the whole supply chain that creates a valid linkage between the members. We assume that in our system each product is attached a unique information RFID tag. This tag act as a unique digital cryptographic identifier which links a physical product to its virtual identity on the network. This virtual identity is presented on the blockchain network as a part of the product digital profile. Not only products should have their own digital profile, but also each entity should have its unique digital profile on the network which should be created upon registration. It is necessary to create a link between the products profile and the engaged entity after contract signature. In order to solve the entities confidentiality through the network, the system allows entities to alter the privacy status of their profile to different types of entities.so, in this way, entities can choose to remain completely anonymous, however must be certified by a registered auditor or certifier to maintain the trust in the system.

The proposed systems is composed of following members with the specific role which are:

- **Registrars** – provides unique identities to entities on the network in order to add the validated members in the system.

- **Standards Organizations** – defines standards schemes such as Fairtrade policies and regulations.

- **Certifiers** – provides certifications to entities, which allow them to participate in the network.

- **Suppliers, manufactures, distributors, wholesalers, retailers, 3PLs, and waste management organizations** – enter key product specific data to the blockchain and update the network

- **Consumers, business institutions** – purchases products, and in some cases are allowed to enter product data to the blockchain.

Upon registration by registrar, for the sake of entities' security and confidentiality, a public and private cryptographic key pair are generated for each entity. The public key recognize the entity within the network and the private key authenticates the entity when interacting with the system. Entities can only interact with the network by cryptographically authenticating themselves using their private key. This allows each product to be digitally signed by the entities when being exchanged or added to further down in the supply chain.

Undoubtedly, each entity is only allowed to enter the specific data in specific phase of the product through a user interface in the network. It means, the software application used by the entities is configured for specific digital profile of a product. The system software is created and developed by a professional group of trusted parties, and is only accessible for registered organizations and institutions to download, run and access on their systems. Consumers just have customized version of the user interface which allow them to access data about a product they have bought. Thanks to the smart contracts, by writing programmable codes and embedding it in the blockchain, each entity depending on their type and positions in the network can access data and update the current product status and add new information after a specific condition is met. Meaning that, only this entity has the permissions to enter new information into that product's profile or initiate a trade with another party. For instance, if a product is in the wholesale phase, the first tier suppliers of that specific product cannot enter new data in that unique product profile because the system is locked for them thanks to automated code execution program based on smart contracts. These specific rules define how the entities in the network are to interact with the system, and how the data will be shared among the network. Therefore, when the product is transferred (or sold) to another entity, both parties must sign a digital contract to authenticate the exchange. When all parties have signed the contract, the details of the transaction will be added to the blockchain.

In order to maximize the transparency of system elements, and maintaining the integrity and security of data, all of entities have to be audited and certified by certifiers by visiting the factories and facilities to inspect and audit if the rules/policies for standard programs are being met. Then, after certifying, they digitally should sign and confirm the entities' profile and their product profile. In addition, the certifiers must disclose all entities' identity to the network through a registrar.

By using this proposed system some competitive advantages has been created such as product location thanks to RFID and blockchain technology, current status of the product specially when dairy-food products are introduced through the system to have access to the quality, safety, and environmental impacts and also having access to time of transaction in product journey thanks to recorded time by the system which is called time stamping advantage of the blockchain.

In addition, in the sale points, the customers can use the RFID reader to obtain the basic information of products by scanning their RFID tags and, on the other hand, thanks to blockchain technology, all the information along the manufacturing supply chain is fully auditable, which means customers can also have access to detail information about the final products in a real-time manner by inspecting the blockchain system. Finally, due to the strong integrity properties of the blockchain, this information can be genuinely trusted.

4.3 Product profile

The main question which comes to mind in the proposed forward logistics blockchian system is about this issue that what kind of specific information about product should be added to product profile both in RFID tags and blockchin platform in order to use them further in reverse logistics flow and to integrate it in the system for closed-loop supply chain perspective. In Table 4-1we have presented these specific information which must be stored in the tags and platform and the relevant description of each.

Table 4-1: product profile data

Data	Description
Tag ID	It's a specific EPC which is unique for the product. And acts as a fingerprint for the product. And further product information are related to this.
Producer code	Shows the specific code of each entity
Product specifications and image	It shows a brief description of the product with the product image.
Seller(retailer) code	It identifies the seller who has sold the product to customer
Product category code	It identifies the product category code in order to know the related information about the product disassembly, recycling, repairing, recovering and further required information which mainly are used in reverse logistics activities.
Price	It is important specially at the time the similar product with different prices by different producers and retailers is sold to the consumers(based on the market type and their location place)
Bill of material(BOM)	It identifies product bill of material
Item service history	It shows the product reverse logistics services history such as repairing, changing, and…
Return code	It represent the return reasons and helps in selecting the best categorization channel
Production date	It is completely essential specially at the time that expired products should be recognized and it is a suitable mechanism for pricing strategies and valuation on return products

Customers details	This gives us information about customer specification, taste and attitudes, customer geographical location, and … for segmentation, advertising issues , and customer categorization purposes
Service level agreement(SLA)	These information is important to know for keeping financial resources and other organizational resources, and the way of performing and agreed level services.
New product ID	In case of reverse logistics operations such as repairing, recovery, redistributing, reusing and then linking this ID with the original one in order to enable product tracking through its life cycle.

4.4 Reverse logistics network platform

To develop this model in reverse logistics activities, the first mandatory condition is the confirmation of the returns collection & separation centers by certifiers/legal authorities in order to assure other entities in forward logistics and security of the chain. It means, without this specific certification they cannot register in the chain by registrar. After this validation these centers based on returns alternatives can update the product profile information and modify it in the blockchain network and then assigning them a public and private cryptographic key to log-in by registrar. Due to the existence of different RL operations we analyze each of them based on 2 different scenarios. First one indicated the situation in which it's necessary to assign a new ID to the product while in another one there is no necessity to assign a new identity code to the product because we are not going to process it again in our chain. Therefore, the process for these 2 scenarios is different. In Table 4-2 we have presented the procedure based on these 2 scenarios.

Table 4-2: integrated solution based on RL operations

Scenario	RL operation	Direct engaged entities	Process
1	Reuse/resale	-Wholesalers, retailers, 3PLs -consumers, business institutions	After receiving the used product from customers by certified collection & selection center, they update the product profile in the blockchain network by public and private product key. Then, the experts inspect the product to diagnose required RL operation. Therefore, after recognition, they sign a contract with direct engaged entities based on RL operation to change and redistribute of the used products. For this operation the collection& selection center create a new identity on the blockchain network and link it to the original
	Repairs	-consumers, business institutions	
	Remanufacturing and/or refurbishing	-Wholesalers, retailers, 3PLs -manufacturers & packaging	
	Recycling	-manufacturers & packaging	

			product ID and also update the product profile. Then sending the item to the direct engaged entities.
2	Incineration	-Released energy captured companies	After receiving the used product from customers by certified collection & selection center, they update the product profile in the blockchain network by public and private product key. Then, the experts inspect the product to diagnose required RL operation. Therefore, after recognition, they sign a contract with direct engaged entities based on RL operation to change and redistribute of the used products. For this operation the collection& selection center update the product profile. Then sending the item to the direct engaged entities. Finally, finalize the product life cycle and close the status of the product in their blockchain platform.
	Redistribution of new spare parts/goods to new users	-new users/industries	
	Waste disposal	-disposal centers	

4.5 Case study

In this section an example is explained to better clarify the potential for the proposed concept. In this model (blockchain & RFID application model) the supply chain is considered for the first tier suppliers, manufacturing, distributing, and different RL operations of a bicycle.

As shown in Figure 4-1 graphically, a bicycle is composed of many components such as frame, tires, chain assembly, and so on.

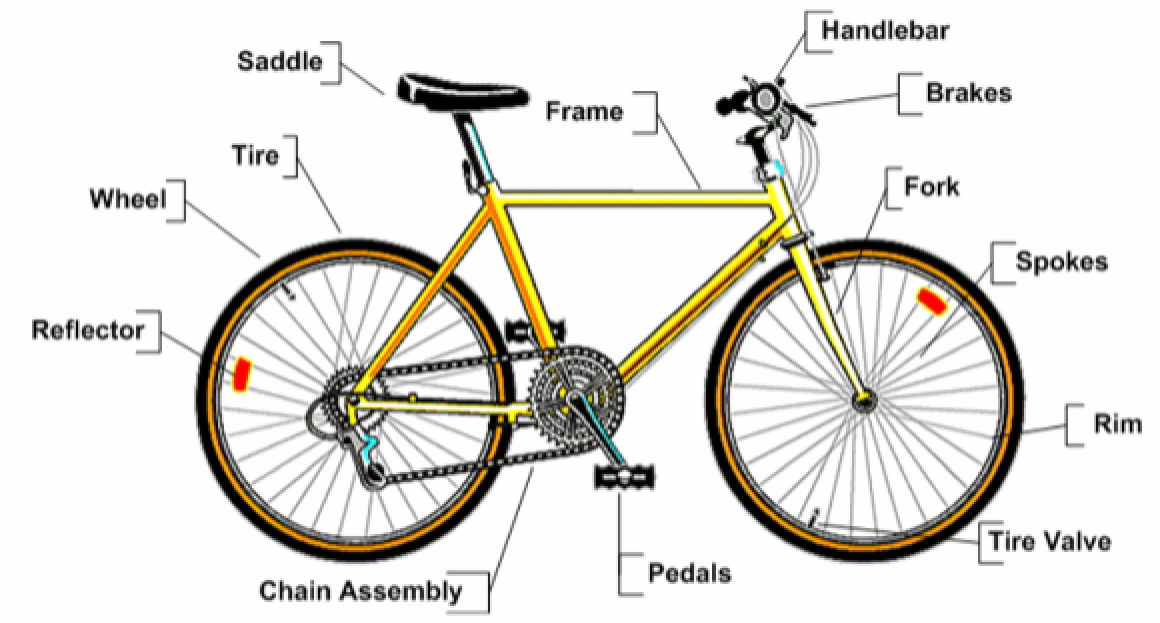

Figure 4-1: bicycle components

In addition, it's presented in Figure 4-2 the bicycle's bill of materials. Thus, to manufacture or assemble one bicycle, we need one frame, two wheels, 72 spokes, and so on.

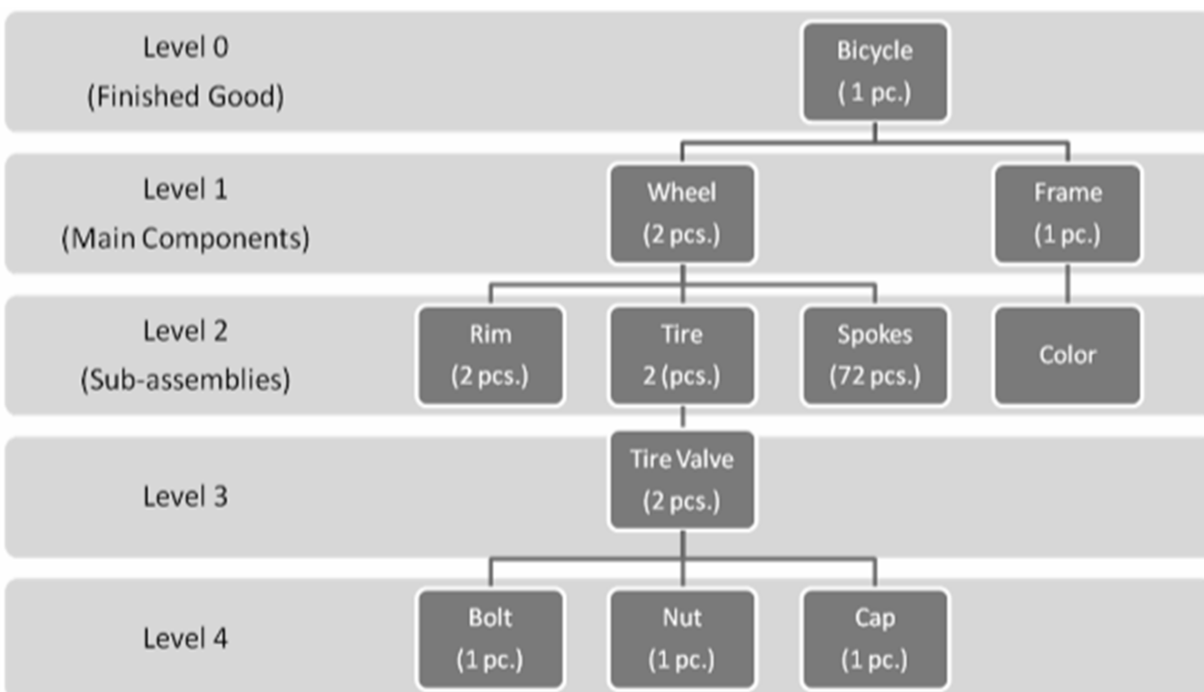

Figure 4-2: bicycle's bill of materials

For the sake of simplicity and integrity we assume the production of bicycles based on following general assumptions:

-bicycle production quantity: 1000

-distribution batches capacity: 500 qty

-container capacity: 2000 qty (4 batches of 500)

-The number of suppliers: 2

-components produced by supplier1: wheels

-components produced by supplier 2: saddle

-both suppliers and our manufacturer are completely vertical integrated (e.g. raw material is provided by themselves)

-another parts are insourced (produced by the company)

In reality, there are many actors involved in the manufacturing and the supply chain of a bicycle. However, the application of blockchain & RFID in this example is extend to a vertical supply chain by staring from vertical integrated suppliers and then the company. In Figure 4-3 the physical flow of product supply chain is depicted.

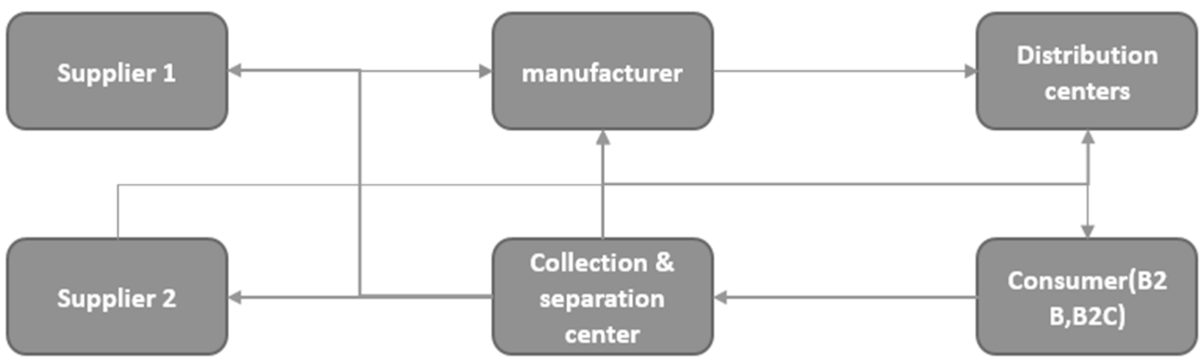

Figure 4-3: physical flow of product supply chain

Furthermore, all entities mentioned in this scenario, have registered themselves in the system through a registrar service, and has their own unique identity on the network (after being certified by certifiers), including an entity profile. The entities interact with the system using the interface created by the system software for organizations and the business processes is involved.

Supplier 1: after producing wheels, the new RFID tag is generated and attached to the product which contain the key product information and entered to the blockchain product profile. Then, a new trade is initiated between the supplier 1 and bicycle manufacturer, where the goods are exchanged after signing a digital contract that stored on the blockchain (the data entry would be through handheld tag readers). For more details, after finishing productions, attaching tags to the products, signing a contract, and updating the system, for the security of transportation we put wheels in packages of 500 qty and plump it with a new RFID tag in order to avoid counterfeiting issues. Because if during transportation someone open the tag, we will be informed automatically. So, since we have produced 2000 wheels (2 wheels per one bicycle). We need 4 packaging RFID tags and due to our container capacity we need 1 container RFID tag. It should be noted that products in packaging packs are linked to packaging RFID tags and packaging RFID tags are linked to container tag to simplify tracking items and categorization. Thanks to smart contracts, after transportation is done to manufacturers, the blockchain system is updated and transaction is completed and is broadcasted to other involved entities.

Supplier 2: the process is the same as supplier 1.but, the difference is about the product and required quantity which is 1000 saddle. Therefore, we need 2 packaging tag and 1 container tag.

Manufacturer: after receiving items from each supplier and then confirming the transaction by scanning them through their network connected scanners. This closes the exchange and gives the manufacture access to read and enter new data onto the product's profile after producing the final product. Hereby, other materials are assembled with the wheel and saddle to create bicycle, which on completion of the product production will have a new RFID tag. Then, after entering key product information on RFID chips, we update the product profile in the blockchain system. It should be taken into consideration that the product profile of this product is updated along with that of the saddle and wheel, to show that they are both one item, with two different tags. This allows the product to be recognized by scanning the product tag. This is crucial for the distribution system. Then like the process of wheel, finished products are placed in packages and containers and plumping them with RFID tags. Finally, after linking them in the system we will deliver them to distributors.

Distribution centers: The next entity in this supply chain is the distributor, who transports the product through various locations in various containers. At each of these locations, the profiles of the products are updated by scanning the tag of the larger container or pallet that contains multiple packages. This makes it easier for products to be updated quickly and efficiently. The blockchain related to the larger container will automatically updates the subsequent chains to enable the traceability of an item in a larger batch.

Retailers (consumer market): after receiving and confirming the products from distributors, they sell the product to the customers. The consumer accepts the product and receive blockchain public product key to log-in and see the product profile to be sure about the originality of the product. And then, the status of the product is updated by seller (retailers) and/or consumer in blockchain platform. In addition, customer details is entered in product profile for advertising, segmenting and management purposes.

Collection & distribution center: many consumers after using the products, are intend to making value from it.so, they sell the product to these centers or may like to repair the product or using these centers as an intermediaries to sell their products to others. In each of these cases, collection & distribution centers after receiving the products, check the status and condition of used products to identify the best RL alternative. At this stage, they benefit from product information stored in RFID tags and product profile in blockchain platform. It means these information helps them to identify and process the flow in a more sufficient way. Based on 2 different scenarios which was mentioned in section 4.4 about reverse logistics network platform, we continue the journey of the product life cycle. If the product is identified to be included in the first scenario, we assign it a new RFID tag and then, we enter into the blockchain product profile and update it by linking the new ID to the original one and updating it in the network, especially item service history, to trace it for further journey. Then, based on required RL operation needed we initiate a trade with the direct engaged entity (for example: in case of reselling/reusing, setting a trade with distributors or for remanufacturing, setting a trade with manufacturer) by digitally signing a contract on the blockchain. In this way, a record of all previous stages will remain on the blockchain and its continuous cycle is progressing until its end life cycle. In case of second scenario, there is no need to assign a RFID tag with new ID. Only, we update the product profile through blockchain and then we close the product life cycle at this stage.

4.6 Advantages and disadvantages

4.6.1 Advantages

Fighting against counterfeiting and grey markets: Thanks to unique ID of RFID tags, products are protected from counterfeiting and grey markets. In addition, due to edit ability characteristics of some RFID tags, many kinds of supply chain information can be added into the traceability system through intelligent equipment. Besides, by using blockchain technology, all the members in this system are unable to manipulate closed-loop supply chain information, which further increases the safety and credibility of the product.

Competitive advantages: Nowadays, by growing customer expectations, and on the other hand, counterfeiting issues companies have intended to increase their competitiveness. Therefore, by using such models (RFID& blockchain), companies would benefit from increasing the sale, reputation, and gaining more market share by overcoming their competitors.

Improvement of supply chain planning, and reaction time: Due to integrity feature of blockchain and RFID real-time adding information, upstream and downstream enterprises in supply chain are integrated together and it would help us to improve supply chain planning, logistics cost reduction, enhancement of efficiency of supply chain, and improvement of efficient reaction in case of happening any emergency in the supply chain like fraud and corruption.

Increase credibility and trust: Frankly, centralized systems are more vulnerable in case of any disruption and corruption in comparison with decentralized systems although they are using RFID technology. Moreover, in these systems, the user will never be able to know the inner details of the transactions. This could lead to information fraud and extortion for supply chain members. On the other hand due to decentralization nature of blockchain technology, we can benefit from the need for a trusted centralized organization and providing an information platform, enabled by RFID, for all the members in it with openness, transparency, neutrality, reliability and security.

Benefitting from tracking and traceability: Thanks to nature of blockchain and RFID technology, all information through supply chain is transparent and open to other members and all members are linked together. So, members have access to real time tracking data about the product in the system. Moreover, consumers can obtain the full information about the product in the whole supply chain which are beneficial to establish a healthy market environment.

4.6.2 Disadvantages

High cost: Basically, most companies that sell RFID tags do not specify prices because pricing is based on some factors such as: volume, the amount of memory on the tag, and the packaging of the RFID tag (whether it's packaged in plastic or embedded in a label, for example), whether the tag is active or passive and much more. Generally, active tags are $25 and up. Active tags with special protective housing, extra-long battery life or sensors can cost $100 or more. A passive 96-bit EPC inlay (chip and antenna mounted on a substrate) costs approximately from 7 to 15 U.S. cents. If the tag is embedded in a thermal transfer label on which companies can print a bar code, the price rise to 15 cents and up. Low- and high-frequency tags cost a little more [135]. In addition, implementing this kind of tags require the establishment of a series of equipment such as readers tags machine in factories, various kinds of hardware and software, upgrading and transformation of the original logistics systems, and personnel training cost. Consequently, considering these conditions seriously restrict the application and popularization of RFID technology in the logistics area.

The size of the blocks in Blockchain: Although the blockchain is in its initial phases, there are some problems related to the size of blocks. Initially, every time the transaction is done during our closed-loop supply chain model, the size of the database will grow. It will causes the storage problems for the blocks. Subsequently, every node has to maintain the chain to run, the computing requirements (e.g. needed time to accomplish the transaction) increase with each use.

5 Conclusion

To conclude, in this study we proposed and demonstrated a platform/model for adoption of blockchain technology with RFID in closed-loop supply chain networks to solve available supply chain problems arising from complexity of supply chain networks and existence of lack of trust and then transparency in the supply chain, traceability and counterfeiting issues. The evolution of blockchain and RFID-based supply chain management is discussed which enables the creation of shared, secure, decentralized ledgers, automatic digital contracts (smart contracts), and trustworthy.

Regarding the concept of closed-loop supply chain, it should be mentioned that Reverse logistics networks are more complicated in comparison with the forward logistics networks from information processing perspective. Therefore, implementing blockchain and RFID technologies are more controversial and challenging in this area. And information standardization on reverse logistics processes are very important. To reach this, it is vital to make effective infrastructure for information and integrate forward logistics with reverse logistics to use sufficiently the information embedded in the forward flow of the product. Blockchain and RFID technologies together can help companies to facilitate this integration. On the other hand, by utilizing these technologies, they can benefit from different points such as: increasing transparency, openness, collaboration, traceability, and trust among different actors and also fight against counterfeiting. However, some challenges are existed for adopting these technologies combination together such as: high implementation cost specially RFID tags and the size of the blocks in the blockchain. Obviously, with the application of these technologies, products can be understood, tracked, checked, and trusted as they travel along the supply chain and in case of adopting the proposed system, presented in this study, from the starting point of product journey in forward logistics, collection and selection centers in reverse logistics flows can make a better decisions about the suitable RL operation for that product. Then, as a result, the comprehensive information would be available for the whole life cycle of the product. So, customers' satisfaction could be increased too. And guarantee the product with the accurate information. By all and all benefits, further studies is necessary about the appropriate cost evaluation of adopting such system in closed-loop supply chain, improving, and investigating the model effectively. In addition, Investigations are needed to evaluate more effectively the case studies and pilot programmes and provide valuable practical information to improve blockchain implementation. Post-implementation success and failure indicators of such technology can also be addressed in the future research. Finally, Understanding the full implications of blockchain technology with RFID in the closed-loop supply chain will require more efforts (noting that no study is done so far about adaptation of blockchain technology and RFID with closed-loop supply chain perspective in order to focus more and precisely on reverse logistic flows). Subsequently, professional organizations need to be involved and cooperate with academia to develop standards and provide practical performance measurement on blockchain technology implementation.

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