RFID based Smart goods and infrastructure

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Abstract
This report mainly focuses on RFID based smart goods and their effect on supply chain intelligence and local decision making. In today’s supply chain for making any decision, it is required to make a connection to central data bank system. Among some vertical transactions between a special supply chain level and central part, decision is made. As it will be discussed in the report this structure has many disadvantages. The report tries to introduce a smart infrastructure that is based on decentralized decision making enabled with smart goods.

In this report several ways of distributing intelligence and providing smart logistic system with the help of different technologies will be discussed and compared according to their advantages and disadvantages. The report introduces a smart infrastructure containing smart goods, RFID tags and readers that supports local decision making idea and intelligence distribution concept. Also smart freight benefits and possibilities in supply chain are discussed in the report.
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3.4.1 Communication technologies for very long distances .................................................. 14
3.4.2 Communication technologies for long distances .......................................................... 15
3.4.3 Communication technologies for short distances......................................................... 16
3.5 Auto identification ........................................................................................................... 16
   3.5.1 EPC.................................................................................................................. 16
   3.5.2 RFID.............................................................................................................. 19
4. Smart logistic system ........................................................................................................... 24
   4.1 SLS..................................................................................................................... 24
   4.2 Centralized system ............................................................................................... 25
   4.3 Decentralized system ............................................................................................ 26
   4.4 Smart infrastructure ............................................................................................. 27
   4.5 Smart goods ......................................................................................................... 29
5. Smart freight benefits ........................................................................................................ 33
   5.1 Direct benefits to private firms ................................................................................ 33
      5.1.1 Increased Efficiency and Productivity ............................................................. 33
      5.1.2 Improved Reliability and Service ................................................................. 33
      5.1.3 Enhanced Shipment and Service Integrity .................................................. 34
   5.2 Public Sector Benefits ............................................................................................ 34
   5.3 Freight Network Benefits ....................................................................................... 34
6. Supply Chain consequences ............................................................................................. 38
   6.1 RFID in Supply Chain Management ....................................................................... 38
   6.2 Supply chain intelligence ....................................................................................... 38
   6.3 Local decision making ........................................................................................... 39
   6.4 Intelligent decision making .................................................................................... 41
7. Conclusion ........................................................................................................................................44
    7.1 Outcome ........................................................................................................................................44
    7.2 Further research ........................................................................................................................45
References ............................................................................................................................................46
Figures:

Figure 1, methods levels .............................................................................................................. 2
Figure 2, general transportation system outline (Lumsden K., 1995) ......................................... 5
Figure 3, flows in transportation systems (Lumsden K., 2004) .................................................. 5
Figure 4, Levels of intelligence and smartness (Franzè 2003) .................................................... 7
Figure 5, EPC data format, (http://www.epcglobalinc.org) ...................................................... 17
Figure 6, EPC Network Architecture components (Clark et al. 2003) ....................................... 18
Figure 7, RFID tag ..................................................................................................................... 19
Figure 8, RFID gateway reader ................................................................................................. 19
Figure 9, Sources of RFID cost savings, (B.S. Vijayaraman and Barbara A. Osyk, 2006) ...... 21
Figure 10, the benefits of utilizing RFID in freight transportation, (Boushka et al., 2002) ...... 22
Figure 11, RFID advantages in three tagging levels, (IBM 2004, Adapted by Lumsden and Stefansson 2007) .................................................................................................................. 23
Figure 12, The Smart Logistics System concept, (Niclas Alvergren, et all, 2007) ................. 24
Figure 13, centralized information concept (Lumsden and Stefansson, 2007) ..................... 25
Figure 14, decentralized information concept (Lumsden and Stefansson, 2007) ............... 26
Figure 15, Decentralized decision making points (Karimibabak, 2005) ......................... 27
Figure 16, toward the concept of smart infrastructure, (Alvergren, N., et all, 2007) .......... 28
Figure 17, smart infrastructure and the new paradigm, Smart Supply Chain (Lumsden, 2007) ........................................................................................................................................ 30
Figure 18, New smart supply chain (Karimibabak, 2005) ..................................................... 31
Figure 19, asset tracking technologies, (transportation, 2005) ................................................. 36
Figure 20, General supply chain (Lumsden, 1998) ................................................................... 39
Figure 21, RFID integration layer (Karimibabak, 2005) ..................................................... 41
Tables:

Table 1, XML and EDI comparison, (http://www.tdan.com) .....................................................13
Table 2, RFID advantages, (US department of transportation (DoT), 2005) .................................21
Table 3, Chain integration dimensions (Lee and Whang, 2001) ..................................................29
Table 4, potential advantages of intelligent freight, (US department of transportation, 2005)...34
Table 5, different areas for intelligent freight, (US department of transportation (DoT), 2005) ..35
Table 6, delivery service items ..................................................................................................39
1. Introduction
Nowadays, companies are interested to use RFID facilities for increasing transparency and efficiency in their supply chain. This report focuses on development of intelligent system using RFID for enhancing local decision making in different levels of supply chain.

EPC is one of the solutions for decision making in supply chain but in EPC global solution, the data related to each marked good is stored in centralized stores therefore there are plenty of vertical transactions between every node in the supply chain and the centralized store and data base. This will need a giant storage space in the centralized store and also needs lots of CPU work to extract information and decision from the centralized store.

The idea behind this report is to investigate local decision making system using RFID for making goods to be smart. Smart goods are those kinds of goods that can communicate and carry their own information with themselves with the help of RFID labels and tags.

1.1 Background
It is one of the most interesting areas to provide an infrastructure where the actors can make decisions without referring data to the central station for checking and making decisions. For providing such infrastructure an advanced information system is required to be able to share information through the whole supply chain.

RFID is one of the most popular and advanced information technology nowadays that offers various number of applications. These applications give the possibility to have a smart infrastructure that can make decisions locally whenever needed with the help of information provided by RFID on goods, vehicles and infrastructure.

This technology provides applications that are economically efficient and also time saving. This technology reduces human works and errors and also provides an intelligent system that decisions are made according to the local data provided by smart goods (goods with RFID tags).

1.2 Purpose
This report main focus is to introduce a RFID based method to enable local decision making in different parts of supply chain. This report will offer a smart infrastructure able to make decisions in a local level with the help of goods enabled with RFID. Theses goods can carry their own information through the chain and it is available for all the users and actors in supply chain.

As there can be much functionality offered by RFID because of its abilities, it is important to identify how RFID can improve the smart infrastructure and what services it can offer to this system. Also it is important to identify how it is possible to distribute intelligence so that local decision making becomes possible.
Another important issue to be considered is compatibility of RFID system with other technologies and systems that are applied in companies and organizations.

1.3 Methodology
This report has involved literature studies and some relevant case studies in the area. As there were not adequate books and journals about smart freight, some of the information is brought from white papers and some other reports done in related areas such as RFID, Smart infrastructure, ITS and etc.

This report contains three major subsets including introduction, analyze and solution.

In the first part (introduction) some basic theories required to be understood are brought. This part provides the required background for followed parts of the report.

The second part (analyze) includes ideas to provide a smart infrastructure and smart goods within this infrastructure. This part includes centralized and decentralized concepts, smart goods, smart logistic systems and their advantages for SCM.

The last part (solution) includes some solutions for supporting the ideas described in previous part. This part contains a suggested solution for intelligence distribution to enable local decision making and finally a conceptual system design will be presented for supporting ideas described. Following figure is an illustration of contents in each part of the method used in this report.

Figure 1, methods levels
1.4 Limitations

This report is a theoretical description of local decision making and RFID based smart goods and there were no implementation test for the model suggested. Also because this subject is a new area in logistics, there are not enough written documents about, therefore this report is based on existing documents (including white papers, case studies, etc) and also reports of US department of transportation (DoT).
2. Theoretical frame of reference

This chapter includes the main concept of transportation system and introduces different flows in this system and importance of each flow in efficiency of the whole system.

2.1 Smart Transportation systems

This chapter aims to introduce basics of a transportation system, its components and different kinds of flows in transportation. Thereafter it is discussed that why intelligence and smartness is required in such systems in the supply chain. According to economical goals and processes there are different kinds of transportations.

2.1.1 Transportation system

As it is obvious transportation systems are all kinds of systems and activities that transport and convey goods, resources and human from one location to another location in the supply chain. These activities add value to the good or resource being transported. For instance the resource being transported from area A to area B is not available in area B so the resource has that much value for area B to transport it from area A to there.

Transportation has different modes such as ship, air or truck transportation. Each transportation is accompanied with various types of interactions between transportation process and other actors in the supply chain. Each transportation system includes two main components that are nodes and links.

2.1.2 Transportation network theory

As mentioned before transportation system aims to convey goods or resources or people from one point to another point. These points that can be source, destination or just transaction points are called nodes. Nodes are points where activities such as co-loading, reloading, sorting, warehousing and coordination of the process can be performed (Lumsden,K., 2008).

Links connect nodes together to enable actual and physical transportation between nodes. Links represent activities such as the actual transport and movement process of the goods. Following figure illustrates a general transportation system and its components (Lumsden,K., 2008).
2.1.3 Type of flows in transportation systems
Lumsden (2004) has described four types of flows within a general transportation system. These flows are: material flow, information flow, monetary flow and resource flow. Following figure illustrates these flows within a transportation system.

1. The material flow/goods flow: material flow includes all kinds of flow carrying goods and products within the chain between and inside companies and organizations.
2. **The information flow**: this flow includes all the information exchanged between different levels of a company or among actors in the supply chain. Material flow without information flow doesn’t have any value. Because each good should be able to be identified with information that is attached to it.

3. **The resource flow**: resource flow represents the usage of resource among transportation. Resources are divided into two types in transportation, which are static resources and dynamic resources. Static resource are the type of resources that are not movable such as warehouse, road, etc and dynamic resources are movable resources such as trucks, containers etc that move within the supply chain.

4. **Monetary Flow** – this flow includes the money and capital being exchanged between the actors of the transportation (sender, receiver)

**2.2 Why do we need Smart Logistic System?**

As it will be described in this report, Smart Logistic System includes three important components that are smart goods, smart vehicles and smart infrastructure. Supply chain is a chain including different actors and levels each with a specific goal but the final goal of each supply chain is to satisfy the customer with the efficient, effective and on time responses and services. One of the biggest obstacles in this process is lack of transparency and integration among different actors of the supply chain.

Increasing transparency through the supply chain can be gained by increasing smartness and integration through the supply chain. Using Smart Logistic System and smart goods will help the members identify goods without need of asking the central database. Smart Logistic System provides all the actors in the supply chain with real-time information about the goods, their position, the amount of them in warehouses, their arrival time to the destinations and other valuable information. This information increases the security and transparency, on the other hand reduces the level of stock in retailer places, and reduces complexity of warehouse management and inventory management.

By implementing Smart Logistic System, error rate and human (manual) work will be decreased and replaced by automatic scanning devices that are able to scan the whole container when passing the gateway equipped with RFID readers. Therefore supply chain can reach its goal in a shorter lead time.

**2.3 Smartness and intelligence**

It is one of the most interesting areas to integrate goods in supply chain with information to increase their smartness or intelligence. Therefore it is necessary to understand what is meant by smartness or intelligence.
It is one of the assumptions by some of the researchers that computers can be as intelligent as human being and also can be integrated to human being as data chips to provide human with more capabilities and smartness. One of the most popular discussions in this area is Chinese room case.

Chinese room case was designed by John Searle (1980) to show the difference between smartness and intelligence. In this case a person who doesn’t understand Chinese sits in a room and Chinese words and characters pass through that room. In this room there is a book containing rules to manipulate these characters to other characters. These rules make the output and the output is sent out of the room for instance one rule is that whenever the input is A the output should be C. Therefore the interviewer sends the questions to the room and gets the answers out of the room without knowing that the person inside the room doesn’t understand Chinese. This system can pass Turning Test which is designed to test the machine’s ability of doing human-like activities or conversations.

Smartness in transportation system can provide efficient interaction among different actors and levels (goods, resources, actors) of transportation to satisfy the customer requirements in the best efficient way. After having a smart transportation it would be the time to integrate this smart infrastructure with other parts of the supply chain. The data should be attached to the goods to enable smartness through the whole chain.

Intelligence refers to understanding and the manner in which valuable information is collected as it has been described in oxford dictionary. Smartness is a subject given to a person or a thing that has intelligence. Following figure shows different levels of smartness and intelligence.

![Figure 4, Levels of intelligence and smartness (Franzè 2003)](image-url)
3. Technologies supporting Smart Logistic Systems

This chapter focuses on different kinds of information technologies used in the world including a brief summary of ERP systems, EDI, XML, their advantages and drawbacks. This chapter aims to compare different technologies and choose the best one for implementing Smart Infrastructure.

3.1 Enterprise Resource Planning

ERP is an information system that provides activities such as production planning, material requirement planning (MRP), capacity requirement planning and manufacturing resource planning (MRPII). ERP can support business functions including manufacturing, SCM (Supply Chain Management), financials, projects and CRM (Customer Relationship Management) with the use of a shared data store. (Wikipedia)

This system has the ability of resource planning and identifying the flow in which they should move within (materials, employees, etc). ERP is an Information Technology term referring to a hardware or software system that serves all departments within an enterprise. (Wikipedia) This term means that ERP is designed to plan all the firm’s resources and was firstly used by the Gartner Group of Stamford, Connecticut, USA.

Including various modules each responsible for a special business function ERP can act like a company’s manager. These modules include master scheduling, forecasting, finite scheduling, material planning and so many other functions. By sharing information among modules ERP integrates all the activities inside the organization (Hicks and Stecke, 1995).

This system includes a centralized database that can be accessed by all the modules in the ERP system. This eliminates multiple entries of same data by different modules. Large firms usually put a huge budget for ERP implementation and most of it’s modules(Chalmers, 1999) but smaller firms use a few modules or a few components of each module based on their companies’ requirements and specifications(Ferman, 1999).

3.1.1 ERP benefits and limitations

One of the primary objectives for installing ERP as well as one of its principle benefits is ERP ability to integrate all business processes (Brakely, 1999; Davenport, 1998, 2000). ERP implementation helps to improve customer satisfaction. NEC Technologies implemented ERP and gained more speed of order processing, reduced its customer-service response time and improved its invoicing (Michel, 1997).

As Appleton and Brakely(1997) have mentioned ERP also reduces inventory cost and improves efficiency in organizations. ERP helps in lead time reduction which itself brings more customer satisfaction. ERP implementation brings plenty of advantages that some of them are as follows:
“drastic declines in inventory; breakthrough reductions in working capital; abundant information about customer wants and needs; and the ability to view and manage the extended enterprise of suppliers, alliances, and customers as an integrated whole.”(Muscatello, J. R., et al, 2003)

Not all the companies that have implemented ERP are satisfied with the results for instance FoxMeyer Drug, a $5 billion pharmaceutical company, claimed major problems were generated by ERP system, and lead to their bankruptcy. This was the result of making wrong orders and excess shipments. (Bicknell, 1998; Boudette, 1999). Dell Computer also claimed that ERP system was not flexible enough to handle their expanding global operations.

It is important to know that ERP provides good capabilities for companies but before implementing ERP there are important levels. Generally 3 important factors affect the ERP choice, which are as following:

- ERP software facilities
- The ERP software price and the money that the company can provide for ERP purchasing
- ERP users’ ideas and opinions about the ERP characteristics and workers moral in organizations

The first factor covers all the facilities that ERP software can provide for its users such as: the ability to add new modules if necessary, providing security, providing real time status, provide appropriate flexibility and etc.

The latter refers to the important factor that how much the company is able to provide for buying an ERP system. This figure has a great effect on the ERP choice for the company.

In other words we can divide the important factors in ERP choice in to three following groups:

- **Business processes**: including the size of the business, the complexity of the business, differences in the conversion processes.
- **Resources** (time and money) : considering the company’s time and money limitations and move within these limitations in choosing ERP
- **Characteristics of ERP software**: including the ability to integrate to other parts of system, providing information for forecasting and about inventory.

### 3.2 EDI

Electronic Data Interchange is a data communication that is carried out in standardized format inside the companies. EDI is an essential element in electronic commerce including electronic exchange of services and goods that has three stages. This exchange has three levels that are: the pre-purchase stage, the purchase stage and the delivery stage
(Schuknecht and Perez-Esteve, 1999). EDI is used in the second stage. EDI utilizes standard document formats for enhancing information exchange in trading business among partners. It improves customer service at the same time as providing cost benefits, through trading partner collaboration (Jenkins, 1989).

EDI was introduced in 1960 and is a communication technology that helps companies to streamline their business regardless of company’s size. There have been so many researches about EDI benefits.” It has been proven that the higher the level of EDI implementation the greater the benefits achievable” (Angeles et al., 1999; Daley, 1999; Edwards, 1998; Swatman ad SWATMAN, 1992). Although, it may takes months or even years for he company to adopt a new technology within its structure (Regan, 1995).

In other word EDI is a set of standards for structuring information that is to be electronically exchanged between and within businesses, organizations, government entities and other groups. (Wikipedia)

The National Institute of Standards and Technology in a 1996 publication defined Electronic Data Interchange as "the computer-to-computer interchange of strictly formatted messages that represent documents other than monetary instruments. EDI implies a sequence of messages between two parties, either of whom may serve as originator or recipient. The formatted data representing the documents may be transmitted from originator to recipient via telecommunication or physically transported on electronic storage media." Also it has been mentioned that "In EDI, the usual processing of received messages is by computer only. Human intervention in the processing of a received message is typically intended only for error conditions, for quality review, and for special situations. For example, the transmission of binary or textual data is not EDI as defined here unless the data are treated as one or more data elements of an EDI message and are not normally intended for human interpretation as part of on-line data processing." (Kantor, Michael, et all 1996. Retrieved by National Institute of Standards and Technology 2008)

Electronic Data Interchange, EDI, is an umbrella term containing a number of standards for electronic information exchange, between or within organizations. EDI aims to automate and digitalize activities which earlier were performed manually. Hence, EDI replaces paper as an information carrier within and between organizations. Possible areas of use for EDI, within logistics, are exchange of waybills or invoices.

As stated above, EDI consists of several different standards; the most frequently used are EDIFACT and XML. EDIFACT was developed by the UN and is the global EDI-standard, defining how information should be structured in an EDI-message. However, XML has risen to a worthy competitor, mainly because it is compatible with more software and systems than EDIFACT. XML is also easier to understand from a human point of view. It’s valuable to mention that EDIFACT is more suitable for those messages that contain large amount of data.
3.2.1 EDI advantages and disadvantages

There are various kinds of advantages and benefits that can be gained by EDI implementation. By following some of these advantages are brought from different researchers’ point of views.

1. “Better responsiveness to customers (proxy variable: customer service quality feedback); and
2. Improved trading partnerships (proxy variable: customer service quality feedback). “
   From Emmelhainz point of view.
1. “Improved trading partner relationships (proxy variable: customer service quality feedback); and
2. Improved intra/intercompany flow of information (proxy variable: user satisfaction with EDI network information). “
   From Sokol point of view.

Also there are some benefits that Lummus and Duclos mentioned as the advantages of EDI implementation which are:

- **Group 1 benefit.** Transaction benefits – reductions in paperwork, reductions in time spent sorting and filing mailed documents, reductions in input errors, improved pay cycle, faster response time, and standardized information.
- **Group 2 benefit.** Information sharing benefits – reductions in inventory, reductions in lead time, improved customer relations.
- **Group 3 benefit.** Competitive benefits – cost savings from reductions in personnel and efficient business operations, effective use of personnel assigned to new tasks, time based competition enhancement.”( Angeles R.; Nath R.,2000)

Also it is cost saving because there is no need to pay for shipping documents and making hard copies of them. It helps information be accurate, adequate and available at the time it is needed. It will lead to better forecasting management, better supplier and customer communication, less input errors and better accuracy of information. EDI decreases employment and administrative costs, reduces the error risk and increases information quality.

One of EDI drawbacks is that EDI implementation needs time and effort in companies not having IT based systems. Another problem is that to get good advantage of EDI implementation in the supply chain it is required to implement EDI in all parts and levels of the supply chain. Also EDI implementation requires a value-added network (VAN) that costs $1 to $20 per message or more.

3.2.2 EDI prerequisites

Petrosky and Emmelhainz (1991) suggested six key requirements and prerequisites for EDI implementation so that the implementation would be successful:

1) Work procedures, (2) Informal organization, (3) Strategy, (4) Resources (i.e. hardware, software), (5) History, (6) Environment.
These six elements should be checked in both companies and partner’s organization for EDI implementation. Also culture and congruence are important factors when implementing EDI in an organization. Trust to the EDI system and also between partners is the most important prerequisite for EDI implementation.

A survey was carried out in 1994 to clarify the most important requirements for EDI implementation from 500 companies’ manager point of views. The summary of the survey introduced 13 key factors for EDI implementation that some of them were assumed as dependent variables and some as independent variables that are brought by following. (Hendon et al., 1995)

- top management support;
- sense of ownership of cross-functional EDI team;
- use of widely accepted EDI standards;
- re-engineering business processes;
- information technology (IT) compatibility;
- trading partner relationships;
- cost-benefit analysis;
- use of value-added networks;
- conduct of pilot projects;
- use of security and auditing controls;
- conduct of training programs;
- availability of clear legal guidelines for such issues as the legality of contracts, electronic signatures, authorizations, etc.; and
- availability of clear guidelines on EDI trading partner interchange agreements.” (Angeles, R., et all, 2000)

There can be various ways for the level in which EDI is implemented in organizations. But generally there can be three levels for EDI implementation that were introduced by Lummus and Duclos(1995).

- Level 1. Transaction level – the supplying firm is using EDI with a few customers for a limited number of transactions
- Level 2. Linked level – the supplying firm has linked EDI with its manufacturing planning system and is using EDI with its suppliers
- Level 3. Integrated level – EDI transactions are event driven, data is shared between the customer and the supplier, EDI transactions are integrated throughout the company

3.3 XML

“The Extensible Markup Language (XML) is a general-purpose markup language. It is classified as an extensible language because it allows its users to define their own elements. Its primary purpose is to facilitate the sharing of structured data across different information systems, particularly via the Internet. It is used both to encode documents and to serialize data.” (Wikipedia)

XML and EDI are completely different but their usage is almost the same regardless of organizations preference to choose one of them. When EDI was created the main focus was
on compressing the size of the messages. Bandwidth supporting EDI networks is very expensive. EDI messages are very compressed and use codes that are complex to understand. Messages in EDI are difficult to understand and debug. Due to EDI complexity, training process is too long and expensive, therefore EDI applications are expensive to buy and maintain.

XML messages are rich in Meta data therefore easy to understand and debug. XML codes are written in such a way that they themselves describe what they are including. According to this the training process will be much easier and costless to buy and maintain.

3.3.1 EDI and XML comparison

Following table has an overall review on XML and EDI.

<table>
<thead>
<tr>
<th>XML e-commerce solution</th>
<th>EDI e-commerce solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimized for easy programming</td>
<td>Optimized for compressed messages</td>
</tr>
<tr>
<td>Requires web server costing $0 to $5000</td>
<td>Requires dedicated EDI server costing $10,000 to $100,000</td>
</tr>
<tr>
<td>Uses existing Internet connection</td>
<td>Uses value-added network (VAN) charging $1 to $20 per message or more</td>
</tr>
<tr>
<td>XML message format learnt in hours</td>
<td>EDI message format takes months to master</td>
</tr>
<tr>
<td>Only requires JavaScript, Visual Basic, Python or Perl script writers</td>
<td>Requires highly trained C++ programmers</td>
</tr>
</tbody>
</table>

3.3.2 XML advantages and disadvantages

As it was illustrated in table above XML has preference in many cases in comparison with EDI. One of the most important XML advantages is that it is an easy learning format and doesn’t need so much time and effort to be learnt. The other is that XML doesn’t have high implementation cost and can use existing system and internet connections in the organizations.

XML doesn’t have so many restrictions as EDI had. Also when implementing XML, it is not necessary to wait for the other partners to adopt each others’ standards.

With XML it’s possible to develop the tags according to organization pace and also develop the tools that are required in the company. XML allows every organization to build its own tag library which suits their needs perfectly.
XML provide each industry with its own tag that sets to meet its unique needs without forcing SC partners’ browser to incorporate the functionality of too many tag sets.

But XML like other information systems has some disadvantages. There is no XML browser on the market yet. Therefore, XML documents should be converted into HTML before distribution and developers have to code their own processing applications.

This procedure is mostly done by writing parsing routines in Java to parse through an XML document, applying the formatting rules specified by the style sheet, and at last converting it all to HTML.

### 3.4 Mobile communication technologies

One important issue in smart infrastructure and SLS is to provide a technology to make it possible for partners in the supply chain to link different information levels with each other.

Therefore it is required to have an overview on mobile communication technologies that can be used in supply chain. Mobile communication concept includes three different groups according to the distances that the wireless technologies can transmit within. (Eliasson & Hosseinpour, 2004):

- Communication technologies for very long distances
- Communication technologies for long distances
- Communication technologies for short distances

#### 3.4.1 Communication technologies for very long distances

In this part there is a list of common technologies for very long distances and a brief description of each technology.

**Nordic Mobile Telephony (NMT450):** this was the first analog technology introduced in 1981 with the ability of 450 Megahertz transmission.

**NMT900:** the second version of NMT transmitted 900 Megahertz.

**Global System for Mobile communications (GSM):** GSM was developed by European telecommunication companies to be the second generation (2G) for digital mobile telephone standard. (Mobilecomms-Technology, 2007) This technology applies Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA) to divide bandwidth maximum capacity into carrier frequencies. To each frequency carrier an eight hour slot is assigned (Mobilecomms-Technology, 2007).

**General Packet Radio System (GPRS):** GPRS is to distribute packets of data from terminals in the system across multiple channels. First it splits the data into packets, then transmits these packets separately and finally reassembles them at the receiving destination.
High-Speed Circuit-Switched Data (HSCSD): HSCSD is a development of GSM with faster data transfers equal to 64kbps.

Enhanced Data for GSM Evolution (EDGE): EDGE is a technology using the GSM network and Eight Phase-Shift Keying modulation (8PSK) techniques that provides a higher data transmission rate.

Third Generation Mobile Phone Standard (3G): 3G is a technology based on standards declared by the Universal Mobile Telecommunications Standard (UMTS). This technology can support circuit-switched and packet-switched data transfer. Data including digitized voice, video and text messages can be handled according to its’ circuit-switched technique. Also based on its’ packet-switched technique, Internet access and applications requiring high bandwidth can be supported (What-Is-What, 2007).

Fourth Generation Mobile Phone Standard (4G): this is a development of 3G and WLAN to gain higher transfer rate. The transfer rates of 4G are estimated to be somewhere between 20Mbit/second to 100 Mbit/second and create possibilities for new services, such as positioning services or real-time information, such as weather reports or traffic information, into the cell phone (IP Tele, 2007).

3.4.2 Communication technologies for long distances

Followings are technologies used for long distances in communication:

Wireless Local Area Network (WLAN): A wireless LAN (WLAN) is a flexible data communication system used as an alternative for, a wired LAN in buildings. WLANs communicate over the air by the use of electromagnetic waves. “Thus, WLANs combine data connectivity with user mobility, and, through simplified configuration, enable movable LANs.” (Pulsewan, 2007)

Worldwide Interoperability for Microwave Access (WiMAX): WiMAX is a wireless digital communications system, a second-generation protocol that allows more efficient use of bandwidth. (WiMAX, 2007)

Mobitex: Mobitex is a digital, packet-switched radio technology first introduced by Swedish Televerket and Ericsson in 1986 that provides a cellular integrated network with distributed intelligence. The reliability for data transmission, fast data delivery in seconds, the longest battery life in the wireless industry and extensive, seamless coverage can be considered as its’ main advantages. (MobitexAssociation, 2007)
3.4.3 Communication technologies for short distances

**Bluetooth:** Mobile and communication companies (Ericsson, Nokia, IBM, Intel and Toshiba) introduced Bluetooth as a short distance wireless communication technology with a transfer rate of 1Mbit/s.

3.5 Auto identification

One of the main required activities in the supply chain is identification of goods flowing in the chain among participants. This action requires large amount of labor according to the type of identification.

After barcodes, automatic identification technologies were introduced and widely used by different members of supply chain. Auto ID technologies offer different kinds of services such as item tracking, inventory management, security and VMI for retailers.

Automatic identification provides more accurate and faster identification with eliminating or reducing the labor work for manually identifications of freights.

3.5.1 EPC

The Electronic Product Code (EPC) is a coding scheme as a development of bar codes. EPC was developed to provide a low cost tracking system for RFID tag attached goods. EPC identifies every item being manufactured.

MIT Auto-ID center created EPC and currently EPC is managed by EPCglobal, Inc., a subsidiary of GS1, creators of the UPC barcode. The Electronic Product Code is going to become the standard for global RFID usage.

EPCglobalinc has description for EPC that shows different components that should be considered for EPC.

- The tag, a chip, an antenna and the packaging substrate
- A numbering scheme that is unique for each object
- Incorporates existing keys, and very recently US DoD constructs
- Ability of connecting and linking physical objects to computer networks

3.5.1.1 EPC structure

EPC is a unique serial number that identifies every item in the supply chain. This system provides supply chain with inquiries whenever the item is inside the supply chain. 96-bit EPC is the most common EPC version containing information about the manufacturer, the type of object and a specific serial number that relates to the specific object being monitored. EPC provides companies with ability of tracking their offerings down to the
item level and enables supply chain with tracking of inventory and supplies within the chain.

Following figure illustrates a basic EPC format.

![EPC Data Format](http://www.epcglobalinc.org)

**Figure 5, EPC data format, (http://www.epcglobalinc.org)**

As it is illustrated each EPC data format includes 4 items:

- **Header**: header identifies the type, length, version, structure and generation of the EPC.
- **EPC Manager Number**: identifies the entity responsible for maintaining the subsequent partitions
- **Object Class**: identifies the class of the objects
- **Serial Number**: identifies the instance(or the unique number for the object)

### 3.5.1.2 EPC system network architecture

As mentioned above EPC network system was introduced by MIT Auto-ID center as a RFID tagged compatible internet architecture. EPC system network is based on centralized system including central information store and decision making. As mentioned before EPC enables universal unique identification of individual items. EPC unique number is encoded in a Radio Frequency Identification (RFID) tag.

Following figure illustrates an EPC system network and its components.
This network includes several components. A brief description of reader, SAVANT, ONS and PML is brought by following:

**Readers**: devices enable to identify tags when they enter to their read range.

**Savant**: “middleware” software for processing data (tag or sensor) that is extracted from the reader. This process includes activities such as aggregation, filtering, counting of tag data and reducing the volume of data.

**ONS – Object Name Service**: The Object Name Service connects EPC to Internet Uniform Reference Locators (URLs) to find more information about the object. These URLs identify an EPC Information Service. ONS also links EPC with websites related to the object.

**Physical Markup Language (PML)**: The Physical Markup Language (PML) is used to describe physical objects in a way that it can be retrieved by human and also machines later in other processes. PML is actually a form of standardized way of describing physical objects. (David L. Brock, 2004)

The EPC Information Service converts data to PML format for the use of other services.
3.5.2 RFID

Radio frequency identification or RFID is one of the best ways of Auto-Id which has been offered and used in many cases. RFID includes three components that are: tag, reader and memory.

Tag is a chip that carries data and is just like the labels in barcode systems that were attached to the freight but with a higher ability. Following figure shows an RFID tag.

![Figure 7, RFID tag](image)

Reader is a device that reads and sometimes writes the memory of the tag and enables the communication of tag and the outside world. Following figure shows RFID gateway reader in Wal-Mart.

![Figure 8, RFID gateway reader](image)

The memory of tags has two types: read-only and read/write memory. Read-only memory for tags operates just like the labels in barcode system that has some information about the freight and can be retrieved by the reader later. Read/write memory is a memory that in addition to giving information to the reader offers the ability of writing on and updating the memory.

Tags are of two kinds: passive and active.
Passive tags are those tags that should be charged by the reader and after being activated by the reader call they send the information required and again they will be passive until the next call.

Active tags have their own embedded battery and do not need to be activated by the reader and whenever it is needed they send the information to the reader. These tags are more used for longer distances.

The range that the tag can be read by the reader depends on several parameters such as tag type, the antenna direction on the reader equipment and etc.

Tags can store more data their memory in comparison with barcodes and they do not need to be read one by one. Huge number of tags can be read and identified without the need of human labor and just by passing through special gates equipped with RFID reader device.

3.5.2.1 RFID advantages
RFID improves supply chain efficiency and effectiveness because it enables companies to track product information and allows greater control and flexibility in managing goods as they move through the supply chain (Jabjiniak and Gilbert, 2004).

If we want to have a general review of RFID benefits we can say that RFID can recognize each item in the supply chain as they move through the chain in an accurate and speedy way. Thereafter it shares this information with the partners that the information is useful for them and enables collaboration and integration in inventory management, controlling and replenishments. This automatic identification eliminates manual scanning that leads to lead time and error reduction. As Kärkkäinen (2003) has mentioned, RFID improves transparency in the supply chain and reduces stock level.

Following figure shows sources of cost savings gained by RFID implementation in companies. As it is obvious from the figure the most important factors were reduction of stock level and inventory losses.
Figure 9, Sources of RFID cost savings, (B.S. Vijayaraman and Barbara A. Osyk, 2006)

There are so many advantages gained by developing RFID as the identification method in companies and supply chain. Some of them are brought in the following table.

Table 2, RFID advantages, (US department of transportation (DoT), 2005)

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction of labor costs</td>
<td>RFID doesn’t need scanning by labors</td>
</tr>
<tr>
<td>Reduction of product loss</td>
<td>RFID helps to identify the place of product loss in the chain</td>
</tr>
<tr>
<td>Improving VMI</td>
<td>RFID enables replenishment and also payment process in VMI</td>
</tr>
<tr>
<td>Integration of supply chain</td>
<td>RFID reduces mismatches between products and their information</td>
</tr>
<tr>
<td>Higher accuracy</td>
<td>RFID reduces the human work and increases accuracy</td>
</tr>
<tr>
<td>Reduction of stock level at retailers’ area</td>
<td>RFID offers real time visibility and reduces stock level</td>
</tr>
</tbody>
</table>

As mentioned there are several benefits and advantages that can be gained by using Auto-Id in freight transportation. A summery of these benefits has been brought in the figure bellow. (Boushka, 2002)
RFID benefits can be categorized according to the level of tagging they are used in. We can consider three levels of tagging including: item, case and pallet tagging. RFID brings various benefits for each level.

Lumsden and Stefansson (2007) have mentioned RFID benefits in three levels of tagging in IBM that is brought by following.
Figure 11, RFID advantages in three tagging levels, (IBM 2004, Adapted by Lumsden and Stefansson 2007)
4. Smart logistic system

This chapter introduces centralized and decentralized concept and then has a brief overview of smart infrastructure and smart goods that are important factors of Smart Logistic System.

4.1 SLS

The Smart Logistics System includes three components that are smart and provide a complete smart logistic system. These levels are as follows:

- **Smart goods/freights** - these are goods that have information about themselves such as their origin, destination and identification code that are provided by RFID tags.
- **Smart vehicles** - these vehicles are vehicles that can communicate automatically whenever needed and transport smart goods through the smart infrastructure such as roads and tunnels.
- **Smart infrastructure** - this infrastructure provides some technologies to connect the information gained by Intelligent Transportation System (ITS) from the infrastructure (roads, tunnels) to different levels of actors in the supply chain. Some technologies supporting smart infrastructure were discussed earlier as mobile communication technologies.

Following figure illustrates Smart Logistics Systems and its components. As it is obvious from the figure all the components are connected to each other and also to the actors in supply chains.

![Smart Logistic System diagram](image)

*Figure 12, The Smart Logistics System concept, (Niclas Alvergren, et all, 2007)*

Smart freight technologies can help to have better monitor and manage of vehicles, their contents, and the networks which they move within them.
Smart freight should have following capabilities as Lumsden and Stefansson have suggested (2007):

- Process a unique identity
- Is capable of communicating effectively with its environment
- Can retain or store some data about itself
- Uses a language to display its features, production requirements, etc;
- Is capable to support local decision making.

4.2 Centralized system

Smart freight provides a better information sharing and integration through the supply chain and improves SCM. There are two kinds of information system through the supply chain which are: centralized system and decentralized system.

Most of the information systems nowadays are using centralized system. This system includes a central data base that the information is sent and received from there and decision is made in this point and sent to the point the goods are. Therefore this system has huge number of transactions between the physical nodes in the supply chain and the central data base. Centralized system has also other disadvantages for instance information that is exchanged in the supply chain and participants are using is not always updated and fresh. Transactions between the central data base and nodes in SC will cause process time and cost increment.

Following figure shows a schematic of centralized system.

![Centralized Information Concept](image-url)

*Figure 13, centralized information concept (Lumsden and Stefansson, 2007)*
4.3 Decentralized system

Goods in decentralized system carry their own information with them so whenever it is needed for the user to know about the goods they themselves can offer this information to the user. This eliminated the need to call the central information system to give information which leads to reduction of transactions and also identification process waste time. Also this will reduce the number of mismatches between goods and their information which was received by delay from central station.

Following figure illustrates decentralized information system.

![Central information](image)

*Figure 14, decentralized information concept (Lumsden and Stefansson, 2007)*

To have a decentralized information system it is required to have smart infrastructure in which all participants store the necessary information about themselves in different levels. These levels include: label level, freight level and resource level.

First level of information in decentralized system is label level. In this level the information related to each package or item should be stored on it such as the date and place of production the weight and etc.

Freight level information is more related to the packages, cartons and boxes carrying tagged items. This type of information includes the number of packages, their destination, country of origin and etc.

Resource level information includes information about the container such as bill for the goods, goods’ description and etc.
When having decentralized system each point in this infrastructure is equipped with the logic that is needed to make a decision when necessary. As it is illustrated in following figure beside the physical flow in the chain each point is equipped with the necessary information to make decisions whenever needed.

Figure 15, Decentralized decision making points (Karimibabak, 2005)

### 4.4 Smart infrastructure

The idea behind smart freight, is to make it possible to have valuable information where and whenever it is needed without wasting time and money. Smart freight is the kind of freight that can communicate and give the user the information that is necessary for making a decision at that point.

In order to have a smart freight this freight should flow in a smart infrastructure including smart physical and smart digital infrastructure. Physical infrastructure includes physical items in the flow of smart goods and freights such as roads, trailers which itself include nodes and links. Digital infrastructure includes the data that should be received and sent between these physical items. This is done by using sensors, cameras and some data bases to store the information. Some of the technologies used in digital infrastructure are: ERP systems, GIS, using data bases and etc.

By integrating physical and digital infrastructure we can gain a network in which the information is shared and transmitted among different actors that is called “virtual road”.

Following figure shows a smart infrastructure including some technologies for digital infrastructure and some services.
Figure 16, toward the concept of smart infrastructure, (Alvergren,N., et all, 2007)

As it is illustrated above this infrastructure has some components including commercial services, public services, digital infrastructure and technologies for communication and positioning.

Commercial services are services provided for different actors in the market to create value adding activities for them such as arrival notice, real-time rout planning and etc. Public services are created to bring advantage to society such as road pricing, E calls and etc. Digital infrastructure provides all the data for services mentioned above and is responsible for making information available whenever needed for each service. As mentioned before virtual road enables information sharing and transactions among different actors’ levels. This transaction is provided by some communication technologies and positioning technologies that have been discussed in chapter 3.

The data that communication technologies are using is collected with some tools like: road sensor, vehicle sensor or digital maps.

One of the important problems with today’s supply chain is to link the information in the central information system with the right products. Some times there are so many mismatches in between and also it needs huge number of transactions between a special point goods are in and the central part. Smart freight carries its own information with the help of identification technologies such as RFID.
Supply chain management aims to fulfill customers’ needs in the best efficient way. SCM has different dimensions that can be integrated. The following table illustrates these dimensions.

**Table 3, Chain integration dimensions (Lee and Whang, 2001)**

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Elements</th>
<th>benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information integration</td>
<td>▪ Information sharing &amp; transparency</td>
<td>▪ Reduced bullwhip effect</td>
</tr>
<tr>
<td></td>
<td>▪ Direct &amp; real time accessibility</td>
<td>▪ Early problem detection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Faster response</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Trust building</td>
</tr>
<tr>
<td>Synchronized planning</td>
<td>▪ Collaborative planning forecast &amp; replenishment</td>
<td>▪ Reduced bullwhip effect</td>
</tr>
<tr>
<td></td>
<td>▪ Joint design</td>
<td>▪ Lower cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Optimized capacity utilization</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Improved service</td>
</tr>
<tr>
<td>Workflow coordination</td>
<td>▪ Coordinated production planning &amp; operations, procurement, order</td>
<td>▪ Efficiency and accuracy gains</td>
</tr>
<tr>
<td></td>
<td>processing, engineering change &amp; design</td>
<td>▪ Fast response</td>
</tr>
<tr>
<td></td>
<td>▪ Integrated, automated business process</td>
<td>▪ Improved service</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Earlier time to market</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Expanded network</td>
</tr>
</tbody>
</table>

4.5 Smart goods

As shown in the figure 15, in decentralized system different nodes should be supported with real time information and also necessary logic for decision making. In order to provide all the points with real time information without the need of calling central station, smart goods should be used. This goal can be gained by implementing RFID tags to freights for enabling them to be intelligent and smart. For instance by implementing RFID tags each
good knows where its origin is, what its destination is, how they should be delivered to their destinations and so many other general and special information.

Also with the help of navigation technologies and communication technologies so many other facilities can be added to smart goods.

As it is illustrated in figure bellow the whole infrastructure will change as a result of having smart goods in the chain. The traditional way was a top-down communication infrastructure but with the help of smart goods it will be altered to bottom-up infrastructure. Because goods know where they are from and where they should be sent and from which route they should be delivered. The smart infrastructure exchanges information with smart goods and calls smart resources with the help of communication technologies. Smart resources (vehicles) are filled by smart goods and store the history of their activities. Smart goods also keep a log of their history and can find their own way through the SC.

As illustrated in the figure above, in order to have a smart infrastructure, smart goods should communicate with smart resources.

If the new smart infrastructure control can be integrated with the traditional control all of the parts of the chain will be integrated with each other and a total visibility is possible through the whole supply chain. In this supply chain every member is equipped with smart infrastructure and also all of these members integrate and share information necessary for
enabling local decision making at each member area. Following figure illustrates a new supply chain equipped with smart infrastructure.

**NEW SUPPLY CHAIN THROUGH NEW INFORMATION SYSTEM SERVICES AND INTEGRATION**

![Supply Chain Diagram]

*Figure 18, New smart supply chain (Karimibabak, 2005)*

Verdaguer (2004) has divided smartness of goods according to their smartness period into two groups including short term smartness (basic smartness) and long term smartness (advanced smartness). The basic smartness is applied to products that can communicate their status (form, composition, location, features, *etc.*) These products can bring potential benefits to the SC in the short term (2–5 years). (Lumsden and Stefansson, 2007) RFID has a short term smartness that enables tracking, identification, updating data and etc. When it comes to the advance smartness level, items are able to asses their own functions such as self-distributing inventory and self-manufacturing inventory in addition to communicating their status. This level has the potential to bring benefits in the long term (5–10 years) and requires a decentralized database and independent items. (Lumsden and Stefansson, 2007) An example of long term smartness is decentralized systems that use
sensors and have a recording history and are able to make decisions and other activities according to the information shared.
5. Smart freight benefits

This chapter will discuss smart freight benefits from different dimensions and aspects of supply chain. As it will be described these dimensions are public sector, private sector and network.

There are various benefits that can be gained by using smart freights that are divided into three groups:

- Direct benefits to private firms
- Direct public sector benefits
- Indirect freight network benefits

In each level there are different advantageous aspects that are illustrated by the following.

5.1 Direct benefits to private firms

Using smart freights has three overall benefits in a private organization including increasing efficiency, enhancing shipment integrity and improving reliability and service.

5.1.1 Increased Efficiency and Productivity

The more the efficiency and productivity are the less operations’ cost will be. This will help to have more accurate, timely, and detailed data about the operating factors processed with algorithms or models and also to better utilize people and equipment.

Intelligent freight data enables operators to decrease administrative loads by reducing goods’ and data processing times and as a result it leads to an obvious reduction of cycle time.

Automated interfaces eliminate most of the stops at weight stations and can reduce non-productive waiting time and wastes. Because of having better visibility and better control systems operators are able to minimize errors, find and fix them immediately or quickly when they occur. Smart freights will help the operators to deliver a given level of service with fewer resources that will enable them to reduce their slack capacity.

5.1.2 Improved Reliability and Service

Better schedule adherence is the main factor for reliability in freight transportation industries. This will lead to winning more profitable customers, customer loyalty, and growing market share.

Better visibility increases operational flexibility. Shipper confidence will be increased because freight transporter will deliver as promised or provide advance notice of problems and even alternative solutions.
5.1.3 Enhanced Shipment and Service Integrity

Smart freight can lead to shipment improvement and service integrity in two ways. One is the identification and validation tools, such as smartcards. The other way is the combination of asset tracking and on-board sensors. Long-distance mobile asset tracking will help to interrupt some crimes in progress. Intelligent freight technologies reduce the risk of shipments being compromised.

5.2 Public Sector Benefits

Public sector also can improve its efficiency and productivity by using smart freight. For instance they can provide larger amount of inspection in an hour. Intelligent freight technologies also provide agencies with higher quality of the service they deliver, because of their more reliable and flexible services.

Smart freight technologies increase security against terrorism, so it can be claimed that they improve national security. Also smart freight technologies will improve safety. These technologies smooth flows in terminals and hubs and have environmental benefits.

5.3 Freight Network Benefits

There are two levels of freight network benefits that are brought as following.

The first level includes the benefits gained by expanding the network implementation.

The Second level of network benefits are the effects that a network has on other industries and their economy which provide higher quality or lower cost transportation services.

To have a better insight about smart freight benefits following table is brought.

*Table 4, potential advantages of intelligent freight, (US department of transportation, 2005)*

<table>
<thead>
<tr>
<th>Potential Benefits of Intelligent Freight Technologies</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Direct Benefits to Private Firms</strong></td>
<td></td>
</tr>
<tr>
<td>• Increased efficiency and productivity, often thought of as cost reduction benefits</td>
<td></td>
</tr>
<tr>
<td>• Improved reliability and service quality, usually thought of as tools to retain good customers and grow market share and revenue</td>
<td></td>
</tr>
<tr>
<td>• Improved shipment integrity, built around a core of security issues</td>
<td></td>
</tr>
</tbody>
</table>
Direct Public Sector Benefits

- More efficient and effective government operations
- Greater national security
- Improved safety
- Reduced environmental effects of freight transport
- Reduced congestion and expanded capacity for transportation infrastructure

Indirect Freight Network Benefits

- Economies of scale and decreasing unit costs of network expansion
- Exponential increase in total benefits as costs drop and usage grows
- Derivative productivity benefits in industries that depend on freight transportation

As mentioned before smart freight helps to monitor and manage vehicles and their contents to a large extent. Smart freight has several technologies that a brief summary of these technologies are brought in the following table.

Table 5, different areas for intelligent freight, (US department of transportation (DoT), 2005)

<table>
<thead>
<tr>
<th>Intelligent Freight Technologies</th>
</tr>
</thead>
</table>
| **Asset Tracking**               | - Tractor and Truck Tracking  
|                                  | - Chassis and Trailer Tracking  
|                                  | - Container Tracking  
|                                  | - Shipment/Cargo Tracking  
|                                  | - Route Adherence Monitoring  
| **On-Board Status Monitoring**   | - Vehicle Operating Parameters  
|                                  | - Cargo and Freight Condition  
|                                  | - Intrusion and Tamper Detection  
|                                  | - Remote Locking and Unlocking  
|                                  | - Automated Hazmat Placarding  
|                                  | - Driver Emergency Call Buttons  
| **Gateway Facilitation**        | - Driver Identification and Verification  
|                                  | - Non-Intrusive Inspections  
|                                  | - Compliance Facilitation  
|                                  | - Weigh-in-Motion  
|                                  | - Electronic Toll Payment  |
Freight Status Information

- Web-based Freight Portals
- Intermodal Data Exchange and Data
- Standards
- Web Services Software
- Standard Electronic Freight Information Transfer

Network Status Information

- Congestion Alerts and Avoidance
- Carrier Scheduling Support
- First Responder Support

Asset tracking capabilities are the core elements of intelligent freight technologies. Asset tracking includes these functions: communications, location determination, access to electrical power, and on-board processing. Freight transportation includes chassis, containers, conveyance units, trailers, pallets, cartons and individual parts. Asset tracking technologies in different levels of transportation (pallet, container, etc.) are illustrated in following figure:

On-Board Status Monitoring offers robust solutions to collect the data, evaluate it, and carry out proper actions without authorization from central dispatch center. To enable these activities there are different kinds of sensors that can provide information and operate when needed.

Gateway Facilitation applications improves the quality of the operations at terminals, inspection stations by providing better security validation and operating efficiency.
Freight Status Information improves the exchange of information and data related to freight shipments between stakeholders.

Network Status Information is essential for improving usage of available transportation capacity. Smart freight technologies can collect and transfer network situation and status to improve the capacity usage.
6. Supply Chain consequences

This chapter investigates effects and consequences of having smartness and intelligence in Supply Chain Management. Also a model for intelligent decision making has been brought to support the idea with a practical model.

6.1 RFID in Supply Chain Management

As Helo and Szekely(2005) have mentioned, SCM manages information flow and goods flow in the supply chain from the point of origin at the supplier level to the following levels such as production and distribution level until the product reaches to the customer. Logistics management is a vital factor in SCM to provide consumers with appropriate and fast responses in an efficient way. RFID provides better inventory integration and visibility, improves distribution and shares logistics information with partners in distribution and retailer levels. RFID tracking abilities make it a key technology for providing the “location” context for “silent” commerce applications in the supply chain.( Galanxhi-Janaqi and Fui-Hoon Nah,2004) RFID provides real time information about the level of inventory and their location in warehouses and reduces complexity of warehousing and human activities.

6.2 Supply chain intelligence

As mentioned before Supply Chain Management goal is to provide the services and products when they are needed where they are needed and in the best efficient way. Supply Chain Intelligence (SCI) provides some mechanisms for evaluating activities in supply chain. These mechanisms should be provided with several items such as supply chain management data, CRM data source, supplier data, customer data, shop floor data, quality management data and etc.SCI should be provided to extract from and load the information to all of the items mentioned above.SCI goal is to improve the effectiveness in process of producing products in the whole chain by the help of evaluating metrics such as Key Performance Indicator(KPI), exception management, collaborative planning and etc.

SCI goal in other word is to improve effectiveness of the supply chain. Supply chain includes some raw materials that several processes are applied to them such as handling, warehousing and distributing to the customers. This has been illustrated in following figure. (Lumsden, K.,1998)
Therefore improving the effectiveness in supply chain means to improve the delivery service to the customer and reduce logistics costs. Delivery service includes several items that are brought in the following table.

<table>
<thead>
<tr>
<th>Table 6, delivery service items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead time</td>
</tr>
<tr>
<td>Delivery reliability</td>
</tr>
<tr>
<td>Delivery security</td>
</tr>
<tr>
<td>Service level</td>
</tr>
<tr>
<td>Flexibility to customer demands</td>
</tr>
<tr>
<td>Information exchange</td>
</tr>
</tbody>
</table>

All items mentioned above are improved by applying RFID in the delivery system. For instance lead time encompasses time spent for ordering, planning, and engineering and at finally distribution. All these activities would be carried out faster and more accurate by enhancing the process with RFID technology.

Logistics costs include handling costs, transportation costs, distribution and routing costs that should be reduced by the help of SCI.

### 6.3 Local decision making

There should be a unit in smart infrastructure that can make decisions whenever necessary. This unit is indeed a connection between the data or information stored on tags and the source. This unit should use information and make decisions and represent this decision to the users and other members and nodes. Also this unit should produce useful data for other parts and send them whenever it is necessary. Enabler should perform intelligent activities that are useful for other partners in the chain. In fact enabler connects all data sources to each other. This unit should read the information from the tags and decide according to this information and then send the decision to these points in the best efficient way.
This system (decision making unit) should include several components to act as an intelligent device. These components are: energy supplier, processor, memory, input device, output, user interface and supportive software. All of these components are described respectively.

**Energy supplier**

The enabler device should be prepared with energy to be able to extract information from tags and make decisions and then forward decisions to necessary points. This supplier should be cost effective.

**Processor**

The processor is the main part of the enabler that simulates intelligence. Actually the processor uses the information extracted from the tags and according to the algorithms and logics that are stored in its memory, the processor can make intelligent decisions and send them as an output to the other points.

**Memory**

As mentioned above processor uses some algorithms and logics to make decisions. So these algorithms should be stored on the memory of the enabler.

**Input**

This system needs a device to read information from different sources and tags and send it to the enabler. This device is RFID reader that enables automatic reading of tags without labor manual work.

**Output**

As mentioned before this system should make decisions and send it to the points that the result is required. Therefore an output standard and device is required that can be integrated with other parts of the information system such as Ethernet or wireless standards.

**User interface**

A programming environment with the ability of debugging, tracing and modifying is required for each system and also intelligent local decision making system is not an exception.
**Supportive software**

The processor should be prepared with intelligent algorithms and logics that can be gained with smart software. This software should provide algorithms for improving security, handling errors in critical situations, and identification of valuable information extracted from tags.

**6.4 Intelligent decision making**

Local intelligence essentially is used to improve efficiency and effectiveness through reducing number of transactions, stock level and also reducing lead time.

The intelligent unit should be able to make decisions by receiving information from different sources and also should send the decision and information related to the decision to point and nodes that are interested to have and use that information. Because sometimes new decision will affect other parts, therefore their information and activity should be altered according to that decision.

Following figure illustrates IE RFID (Intelligence enabled RFID) system integration layer that is used as an interaction layer between IT or information systems and the intelligent system including intelligent decision making point, data-logic router and etc. (Karimibabak, 2005)

![Figure 21, RFID integration layer (Karimibabak, 2005)](image)

This layer provides information necessary for decision making for other modules. This will reduce transaction amount and should be placed in the central information system.

This layer enables the intelligent system to be integrated with several kinds of IT and information infrastructure that are used in companies.

Data objects are those kinds of data that are extracted from the tags and sent to the enabler through IE RFID integration layer for providing it to make decisions.
Business intelligence objects (BI objects) are information that the enabler send to the upper layer (IT level) about the decision it has made.

Also performance logic objects and performance control objects are objects that prepare logic for making smart decisions in integration layer.

This level needs messaging system and methods to communicate with upper and lower level. Extracted data is sent to intelligence distribution module and the intelligence logic is produced according to the information at each special point. Intelligence distribution module includes three layers that are: object distribution layer, intelligence evaluation layer and communication layer.

First layer (object distribution layer) includes updating activities whenever new decision has been made.

Intelligence evaluation layer is used to produce the logic behind each decision making.

Communication layer enables messaging facilities to connect this level with upper and lower levels in this system.

BI evaluation module is another module needed for communication that uses the information and modify them to BI objects usable for upper layer. This module has two layers that are: BI evaluation layer and BI database.

In BI evaluation layer all BI objects are evaluated by the Performance logic objects and Performance control objects that are received from the upper layer. (IE RFID system integration layer)

As mentioned above the other layer of BI evaluation module is BI database that stores all activities and decisions that this layer has made.

Another important component in the intelligent local decision making system is the data-logic router which sends and distributes the intelligence to the right points at the time they are needed.

A summary of the system described above for enabling local decision making has been brought in the figure bellow.
Figure 22, intelligent decision making system (Karimibabak, 2005)
7. Conclusion

This chapter includes the outcome gained by the report and recommendations for future study and research areas.

RFID based smart freight gives opportunity for exchanging centralized information system and infrastructure with a decentralized system. Using goods carrying their information with them provides the opportunity of decentralized concept and local decision making. Decentralized system enables extracting some basic information from the smart good and if necessary it also can be extracted from centralized data store. This will lead to reduction of identification time and better visibility and management within the supply chain. Using a decentralized system is essential to achieve the smart supply chain concept as it links all the actors of a supply chain by sharing information. This could be done using new technologies such as RFID and Smart Freight.

The result of this project is based on literature studies and qualitative input gained from meetings with a logistics expert from Chalmers University of Technology Kenth Lumsden.

7.1 Outcome

This report has been aimed to investigate the possibilities of having a decentralized decision making supported with RFID based smart goods and smart infrastructure. This report has studied the role of smart goods and RFID in Supply Chain Management and its possible advantages for streamlining activities within the supply chain. The report introduced several information sharing systems in supply chain and analyzed their advantages and disadvantages for supply chain. Thereafter RFID based smart goods were introduced as an enabler of local decision making.

The report suggested RFID based infrastructure for local decision making according to intelligence distribution with the help of smart goods.(Karimibabak, 2005) Although different companies have different ideas about system design enabling local decision making that are dependent to their budget, policies and aims.

The infrastructure suggested is based on object oriented architecture that is the best model because of enabling reconfiguration and modification and its flexibility to changes if required in organizations. This development for local decision making can be done according to the requirement in the system of each organization or supply chain.

As a summary this report investigated smart freight and RFID consequences in supply chain and supported the idea of local decision making and decentralized system by suggesting an intelligent infrastructure decision making enabled by RFID. Design outline of the intelligence enabled RFID system can be a starting for actual implementation of local decision making systems enabled with RFID.
The major focused areas and outcomes of the report were:

- Possibilities and advantages of Smart freight and smart infrastructure enabled with RFID in transportation
- Smart goods effect on SCM
- Local decision making system with distributed intelligence

### 7.2 Further research

As smart freight and Smart Logistic System are new issues and there are few researches done about them, this area has many branches that have to be studied and analyzed to identify what the possibilities of this system are. It is of interest to know what advantages these structures can offer to supply chain and other areas of interest and which other areas can benefit from smart goods and local decision making.

It is important to investigate on future development of local decision making and smart goods and what are the possibilities of RFID tags that are enabling this infrastructure.

It should be studied that what services can be provided with RFID tags within supply chain according to amount of information flowing in the chain. It’s of interest to know what security services are that can be provided by RFID and smart goods and how it can help the recycling process in supply chain.
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