

A MODEL FOR IDENTIFICATION OF THE SUPPLY CHAIN INFORMATION GAPS TO BE REDUCED BY USING THE SMART TRANSPORTATION MANAGEMENT SYSTEMS

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ABSTRACT

The purpose of this paper is to create a model for identification of the supply chain information gaps to be reduced by using the Smart Transportation Management (STM) systems. The information gap is considered as the difference between the *value level* of the supply chain information and *support level* of the STM systems for the supply chain information.

Literature studies are conducted to identify the elements of the STM systems and the valuable types of information for transportation and material handling of products in a supply chain. Empirical studies by using interviews and documentations as sources of empirical data are conducted to show how the model could be applied. Interviews with different actors of Swedish industrial supply chains (suppliers, manufacturers, logistics service providers, retailers and customers) are conducted to identify the value of different types of information in a supply chain. Interviews with logistics managers of Swedish industrial and retailing companies and reviewing the documents of companies are accomplished to find the support level of the STM systems for different supply chain information types.

The result of this study is useful for information operators of companies to identify the information gaps that could be reduced by using the STM systems. This paper is useful as a decision support for practitioners to develop the STM systems according to the value of the information that such systems support for actors of the supply chains.

Keywords: Smart transport management (STM) systems, supply chain (SC), supply chain information types (SCITs), information support, transportation.

INTRODUCTION

Every company that is participating in a logistics setup has experienced the importance of effective information flows (Stefansson, 2006). Information integration and data synchronization is significant to achieve the seamless flow of data and the sharing of information among members of the supply chain (Linthicum, 2004 and Evgeniou, 2002).

A growing number of participants in transport operations have led to increasingly complex distribution setups with augmented needs for information flow. The complex services that are given and the problems of data exchange make the execution of value-added services difficult. To be able to solve some of the shortcomings in many of today's logistics setups, frameworks for logistics system using more data and information—often referred to as smart or intelligent—have been developed, such as the smart freight concept, the smart logistics setup (SLS), and smart transport management (STM) systems (Lumsden and Stefansson, 2007; Holmqvist and Stefansson 2007). According to Stefansson and Lumsden (2009), the three main elements of such information systems are smart freight, smart vehicle, and smart infrastructure that should communicate in an integrated way to make advantages for actors of a supply chain. The backbone of the smart transport management concept is based on the need for increased information accessibility and capability to retrieve data and information on site, which opens up opportunities for local decision-making to support the main operations of most logistics service providers (LSP) (Stefansson and Lumsden, 2009).

Recent studies are investigating the benefits from application of the *smart* or *intelligent* transportation systems. Everyday such new information systems and technologies are being applied for increasing the accuracy and timeliness of the information in the logistics and transportation operations. According to the empirical and literature studies conducted by the author, a part of STM information systems and services have focused on increasing exchange of the information types that are not significant in management of the logistics operations. High costs of implementation, education and maintenance related to such systems raise this question in mind of supply chain operators that: *“Is STM an effective solution for information demands of our supply chain?”*

Considerations on the types of information that are valuable for different actors of the supply chains and the activities or functions carried out by using such information is needed as a decision support for further developments of the STM systems and application of them in the supply chains.

According to the discussion above, the purpose of this paper is to create a model to identify the supply chain information gaps that could be reduced by using the Smart Transportation Management (STM) systems. This model is based on comparing the *value level* of different supply chain information types (SCITs) with *support level* of the STM systems regarding these SCITs.

The supply chains studied empirically in this paper are large industrial and retailing supply chains of Swedish companies. The actors that the information value is investigated for them

include suppliers, manufacturers, logistics service providers, retailers and consumers. Figure 1 is illustrating a simplified model of a supply chain that the study is conducted based on.



Figure 1- The actors that value is created for them from the SC information.

Supply Chain Information Types (SCITs) in this paper are the information types in a supply chain mainly related to material handling or transportation operations of the freights in a through the supply chain.

Value of information is used in the same meaning with advantage, importance or benefit of the information for actors of a supply chain.

Function or functionality of information means the operations or tasks that are carried out by using a special type of information in transportation or material handling in a supply chain.

The empirical data collected for this paper are conducted to show how the model could be applied for different types of information in supply chains.

METHODOLOGY

Literature studies are conducted to identify the elements of the STM systems, their related services and the valuable types of information for transportation and material handling of products in a supply chain. An empirical study is conducted to show how the model could be applied for different actors in the supply chains.

The method used is to evaluate the importance level of the mentioned types of information for five different partners (supplier, manufacturer, logistics service provider, retailer, and final customer) through interviews with individuals or companies working as actors of supply chains. For each partner of the supply chain (illustrated on figure 1), three persons representing three Swedish companies are selected that totally make 15 samples. They are asked to determine how valuable or important are the information types in the supply chain for them. The method of evaluation is to allocate the numbers between 1 and 5 to the information types. These numbers stand for 1: without importance, 2: rather important. 3: important, 4: very important, 5: vital.

Another series of empirical data collection is conducted to identify how much the STM systems support the valuable types of information in an industrial supply chain. This empirical work is conducted through filling the questionnaires and interviews with 8 practitioners working as operational managers of Swedish industrial and retailing logistics companies. This group of selected interviewees is working in areas of logistics and supply chain management. The reason for their selection is their experience in the area of information systems in logistics and supply chain management. This investigation is conducted through making telephone conversations and sending the documents for introducing the research objectives and to make a background understanding regarding the research question for the managers. Then answer sheets with structured questions were sent to be filled in the next step. Follow up emails and telephone conversations were used to

clarify further questions and to make sure to receive valid results for the research. In the question sheets the practitioners are asked to indicate based on their experience in management of supply chain and logistics operations how much the STM systems are supporting exchange, preparation or quality of the value-adding types of information in a supply chain. The method of evaluation is to indicate the degree of support with numbers between 1 and 5. These numbers stand for the following: 1: no support, 2: a little support, 3: mediate support, 4: supportive, and 5: very supportive. For both series of interviews the same evaluation scale is used to make the comparison of the gap level simple. Documentations from different companies providing STM systems and services are reviewed for validation of the results of these interviews.

After finding the value level of the identified information types from the perspective of the supply chain actors and evaluation of the support level of the STM systems regarding the same supply chain information types, these two levels are compared to show how the model could be applied for identification of the information gaps in the supply chain that could be reduced by using the STM systems.

LITERATURE REVIEW

Value and Functionality of information

The rise of e-commerce and the development of new information technologies that promise more timely and accurate information-sharing have led to increasing interest in the *value of information*. The value of information as a general subject has been extensively investigated in different textbooks and papers (Wagner, 1969). Also, there has been recent concern about this issue by both practitioners and academics (Ketzenberg et. al., 2007). General research on the value of information has been published in different studies dating back to the 1960s (e.g. Raiffa, 1968 and Wagner, 1969). A number of other more recent papers have studied the value of information in supply chain and logistics setups more recently (e.g. Huang et. al., 2003, Ketzenberg et al., 2007, Sahin and Robinson, 2002, Lumsden and Mirzabeiki, 2008).

A special form of information may be a very significant decision-making factor for one partner in the supply chain but a meaningless piece of data for another player. King and Griffiths (1986) suggested two approaches to estimate the value of information. The first approach is to consider the organization's willingness to pay for the information. This is measured by the budget for books, periodicals and other source of information, plus the individual's investment in time and effort to discover, retrieve and read the information. The second approach is to estimate the cost saving or other advantages that result from having the information. For generating useful knowledge, we should give meaning to the raw data and meaningless information stored in databases. If the data is structured it becomes information in the sense that it can be communicated, analyzed, interpreted or modeled. Knowledge is thus information that has been given meaning by its user through analysis, interpretation or modeling (Stair et al., 2007). Figure 2 shows this value chain, which leads to generation of knowledge from raw data.

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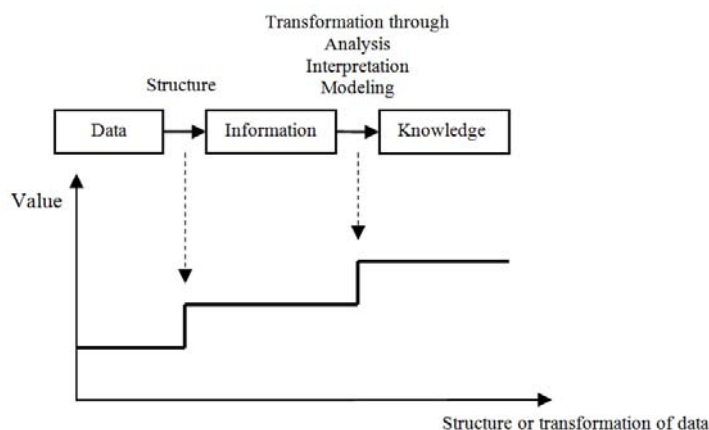


Figure 2- Information Value Chain (Lumsden et. al., 1997)

Hence, for measuring the value of this information in the supply chain, first different kinds of gains and their importance for a special partner should be considered. This means that investment in information systems in supply chains should be correlated with the willingness of different parties to pay for that special sort of knowledge (King et al., 1986).

The relation between the component value chain and the information value chain in a supply chain can be identified (Figure 3). As seen, the value of a special piece of raw data or unprocessed information can be increased through structuring and transformation in different steps (Lumsden et al., 1997). This means that the value level of different types of information for different partners of the supply chain may be dissimilar. Consequently, the level of processing on raw data for each of the partners is associated with the level of their benefits in time, cost and other types of gains generated from this knowledge.

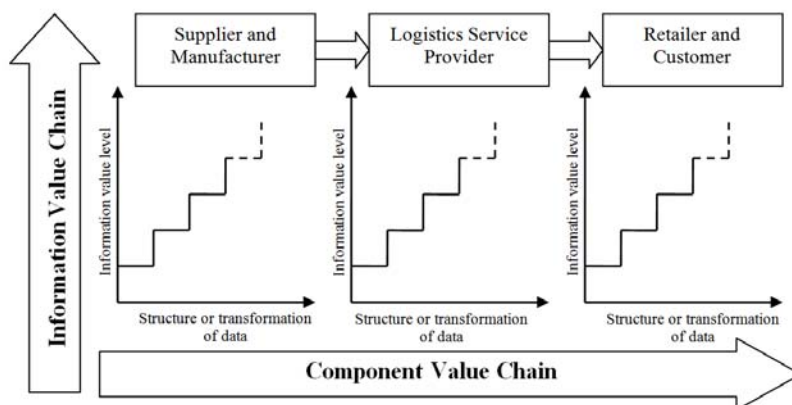


Figure 3- Information Value Chain and Component Value Chain in a Supply Chain (Lumsden and Mirzabeiki, 2008)

There are four reasons showing that timely and accurate information is critical for logistics systems design and operations. First, customers perceive real-time information about order status, product availability, delivery tracking, and invoices as a necessary dimension of customer accommodation. Second, information can be used to reduce inventory and human resource requirements. Third, information increases flexibility with regard to how, when and where resources may be utilized to gain strategic advantages. Fourth, enhanced information

transfer and exchange utilizing the Internet is facilitating collaboration and redefining supply chain relationships (Bowersox et al., 2007).

Functionality level of information is a tool for determining the value of a special sort of information in the supply chain. There are in general two approaches suggested for measuring the value of information: first, to consider the willingness of partners to pay for it and second, to analyze the benefits resulted from that information (King et al., 1986).

Supply chain information systems link logistics activities into an integrated process and this integration is built on four levels (Stair et al., 2007). The transaction system records and initiates individual logistics activities and functions. Decision analysis focuses on software tools to assist management in identifying, evaluating, and comparing strategic and tactical alternatives to improve effectiveness. Management control focuses on performance measurements and reporting. On the lowest level, strategic planning organizes and synthesizes transaction data into a relational database (Bowersox et al., 2007).

Valuable Supply Chain Information Types (SCITs)

In Lumsden and Mirzabeiki's work (2008), published papers and textbooks on information technologies and information systems are reviewed. In that paper, information technologies and systems are studied that they are used or created for increasing the visibility and availability of real-time information in the supply chain. Some of the studied systems and technologies include the following: Enterprise Resource Planning (ERP); Electronic Data Interchange (EDI); Radio Frequency Identification (RFID); Track-and-Trace systems; barcode and scanning; Global Positioning Systems (GPS); and internet applications for the logistics. Out of the mentioned research, a list of the value-adding supply chain information types (SCIT) are generated that create value for different partners of the large industrial and retailing supply chains depending on their position and the structure of their chains. These generated value-adding SCITs are listed in below:

- Location of the products in the supply chain.
- Condition of products in shipment.
- Positioning and sequencing of products in shipments or inventory.
- Inventory level and point-of-sale of retailer for each item.
- Available suppliers information.
- History of sales for each item.
- Warehouse operation information
- Available items of companies for the customers.
- Shipment quantity information in transportation.
- Other information types.

The table 1 shows the valuable types of information for five main actors of a simple supply chain (supplier, manufacturer, logistics service provider, retailer, consumer), the sub-information types related to each type of information and the partner that is having advantage from such information, and value and functions carried out by using such information.

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Table 1- Value adding types of information and their functionalities in supply chain according to Lumsden and Mirzabeiki (2008).

SCITs	Detailed info. Types	benefited partner(s)	Functionality and value of info.
Location of products	<ul style="list-style-type: none"> • Availability of vehicles • Lost or stolen assets • Idle assets • Verify billing/subcontractor activities • Vehicle information such as location and speed • Infrastructure information such as congestions, accidents, special environmental or traffic zones. 	Shipper, LSP, Warehouse operator, Manufacturer	Record keeping; Resource management; Carrier selection; Carries scheduling; Dispatching; Document preparation; Performance measurement; Shipment consolidation; Routing; Shipment rating; Shipment scheduling; Shipment tracing; Expediting vehicle loading; Time efficiency; Higher customer service level; Lower inventory cost
Condition of products	<ul style="list-style-type: none"> • Temperature level • Humidity level • Pressure level • Vibration level • Dangerous goods handling info. • Security info. such as status of the container's lock 	Supplier, manufacturer, LSP	Visibility of the shipment service level for all the partners; Safety issues regarding special handlings like dangerous goods; Health issues regarding the cold chains such as food supply chains and medicine
Positioning and sequencing of products in shipment and inventory	<ul style="list-style-type: none"> • Loading time • Unloading time • Physical location of items in inventory or shipment 	Warehouse operators, Supplier, Manufacturer, Retailer, LSP	Order preparation; Order processing; Reducing labour cost; Accuracy of inventory control; Unit precision
Inventory level and Point-Of-Sales of retailer	<ul style="list-style-type: none"> • Availability of items on retailer's shelves • Number of each SKU in inventory • Number of sold items from each SKU 	Retailer, Supplier, Manufacturer, Distributor	Lower inventory cost; Obsolescence cost; Back order cost; Lost order cost; Availability of items on the retailer's shelves; Better inventory replenishment; Decreasing the bullwhip effect
Available Suppliers information	<ul style="list-style-type: none"> • Availability of suppliers • Prices offered by suppliers • Items offered by suppliers 	Manufacturer	Reduction of procurement cost; Making the transactions paperless
History of sales	<ul style="list-style-type: none"> • No. of items sold from the same SKU in previous seasons or years • No. of items sold from the similar goods 	Manufacturer, Supplier, Retailer	Better forecasting about the orders number and batch size; Better production planning
Warehouse operations information	<ul style="list-style-type: none"> • Product receipt • Material movement • Storage • Order selection 	Warehouse operator, Retailer, Manufacturer, Supplier	Product receipt; Material movement; Better order selection; Inventory cycle counting; Labour scheduling; Equipment scheduling; Lot control;
Offers of companies	<ul style="list-style-type: none"> • Info. about available items at different retailers • Technical info. about the products • Online ordering 	Retailers, Manufacturers, Suppliers	Expanding the market; Reducing the shop-keeping cost; Better customer service level
Shipment quantity information	<ul style="list-style-type: none"> • Deviations in the customer's order 	Retailer, Manufacturer	Less shipment quantity uncertainty ; Adjusting future order decisions

Smart Transportation Management (STM) systems

“A growing number of participants in transport operations have led to increasingly complex distribution setups with augmented needs of information flow, especially electronic messages, between participants in distribution setups. This trend calls for a new kind of

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transportation management system that moves data and information more effectively between partners, increases freight visibility, monitors involved activities in a better way, and increases interaction with infrastructure information to enhance dynamic routing and methods to increase transportation security. This new transportation management system comes in the shape of smart transportation management (STM)" (Stefansson and Lumsden, 2009). The framework suggests improved information visibility and capability of data retrieval from data tagged goods and load units. The three elements of the STM systems are smart goods, smart vehicles and smart infrastructures.

The smart goods

There are different definitions proposed for the intelligent or smart goods that have some similarities and difference (McFarlane et. al. 2003, Kärkkäinen et. al. 2003, Meyer et. al., 2009, Lumsden and Stefansson, 2007). According to McFarlane et. al. (2003), an intelligent or smart good has the following properties:

- Possesses a unique identification;
- Is capable of communicating effectively with its environment;
- Can retain or store data about itself;
- Deploys a language to display its features, production requirements.
- Is capable of participating in or making decisions relevant to its own destiny.

According to Holmqvist and Stefansson (2006), Smart Goods is characterized by a higher level of sophistication than traditional goods identification. This means that instead of using former technologies such as barcodes to identify an item, it is now possible to identify the freight, either individual items or the load unit, with new smart technologies like RFID tag as a carrier of data. Combination of the auto identification tags with sensors that measure and record different physical attributes of the goods are used for creating advanced generations of the smart goods (Lumsden and Mirzabeiki, 2008). Several technologies that are combined for making the smart goods, including RFID, GSM/GRPS and web technology are introduced and explained in the literature (Kärkkäinen et al., 2003; Ghribi and Logrippo, 2000).

According to the literature application of smart goods provides new opportunities for increasing efficiency of transportation operations. According to Lumsden and Stefansson (2007), the concept of smart goods is defined on different levels of packaging such as the container level, pallets level, and item level depending on transportation activities to be carried out in supply chain. There are different classifications based on levels of smartness of the smart goods depending on the level of sophistication of technologies applied in them.

Two levels of smartness are defined by literature for the smart goods. In the level 1 the smartness of the goods is information-oriented based and allows the product to communicate with its environment regarding its status. In the level 2 the smartness of the goods is decision-oriented. In this level the smart goods can influence on their functions in addition to communicating its status with environment and other smart goods (Wong et. al., 2002; McFarlane et al., 2003; Johansson 2009). Examples of the information systems functioning by using the smart goods concept are described in below:

Auto identification (ID) systems for goods management: A basic purpose of introducing the smart goods concept in the supply chain is to maintain the identity of the products. Optical and RFID labels are used for goods identification to fulfill customers' orders, for checking goods in and out of the warehouse, and for keeping an up-to-date inventory. As a result one of the advantages of the smart goods is to increase the security of the supply chains. By maintaining the identity of the product or shipment it is possible to pinpoint where thefts occur and to verify the authenticity of the item and reduce the risk of forgery (Meyer et. al., 2009).

Tracking systems for moving goods through a supply chain: The software and hardware components together make the information systems that are used for controlling the location of the products through the supply chain. Such information systems update the location of the shipments when they pass the checkpoints or they are used for querying or updating product information in general (Meyer et. al., 2009).

Systems for controlling the physical features of the goods: different types of sensors together with an RFID tag and a memory to save the information gives this capability to the goods to store data regarding physical condition of itself during shipment or storage. Temperature, humidity, impact and light are some of the attributes that are stored on memory of the smart tags. This information could be transmitted to the central operation centre as well.

Goods tracking systems: Different applications of tracking technologies are introduced for the retailing stores. Having intelligent shelves in the shops that keep track of the number of items set on them and that send signals when an item from another shelf is placed on them is one of these applications.

The smart vehicles

As mentioned in the previous chapters, smart vehicles are a cornerstone of STM systems. Smart vehicles mainly refer to distribution vehicles or trucks that have their truck cabin equipped with a vehicle computer system; identification of goods is done as freight is loaded on or unloaded from the vehicle. Communication of this information to central systems is not necessarily carried out; in many cases, the information is only stored in the vehicle's computer system, and in other instances, the information is communicated to a central information system, especially if deviations occur or a pre-notification of arrival is needed. Different literature focused on the supportiveness of smart vehicles (Tilanus, 1997; Hubaux et. al, 2004). Some of the systems based on the smart vehicles are introduced below:

In-truck goods identification system: The goods' identification needs to be read from the load unit or from items that are equipped with auto-ID tags. The reading antennas are then often mounted on the roof, side walls, and on the floor of the truck box or trailer. The antennas are linked to a reader and to an onboard vehicle computer.

Navigation tracking systems: Track-and-trace systems using different technologies are used to provide real-time information regarding the placement of the vehicle in the shipment. They can send signals regarding the products' status as well.

The truck and driver information systems: The vehicle management modules typically display and save information from the engine control unit (ECU) and the tachograph. It also

stores details about the vehicle driver, working hours, and driving data, such as fuel conception, distances, etc.

The smart infrastructure

To make the STM framework possible, a new infrastructure for data communication must be implemented, not only in warehouses and terminals, but even in vehicles that transport the goods and the infrastructure used for transportation—roads, tunnels, harbors, ferries, etc. Smart vehicles and smart freights or the load units have to be equipped with communication technologies that indicate the position and status of the goods and vehicle. Such technology enables supply chain operators to react on deviations from schedules and change their plans in accordance to the new situations. Examples of the services based on the smart infrastructure are introduced in below:

Route planning systems: This service makes it possible to perform route planning during the trip in real time. One example is given; if an accident makes the road ahead impassable, a new route can be calculated momentarily.

Missing goods notification systems: On arrival to a destination, the product entities are identified as they are unloaded from the truck and checked against the shipment order / waybill. This service requires collaboration with the shipper's warehouse management system.

Transport delay notification systems: Traffic or road conditions, congestions, etc. can cause delays in transportation, and the vehicle may miss an unloading slot at its destination. By using this service, a notification can be sent from the vehicle to the destination company, including information about the new estimated time of arrival.

Arrival notification systems: This system uses geofence technology to send pre-arrival information to the vehicle's destination. By including the destination company into a geofence, a notification can be transferred when a vehicle passes the boundaries of this geofence (Stefansson and Lumsden 2009).

The Smart Transportation Management systems with its cornerstones and example services related to them are illustrated on the figure 5.

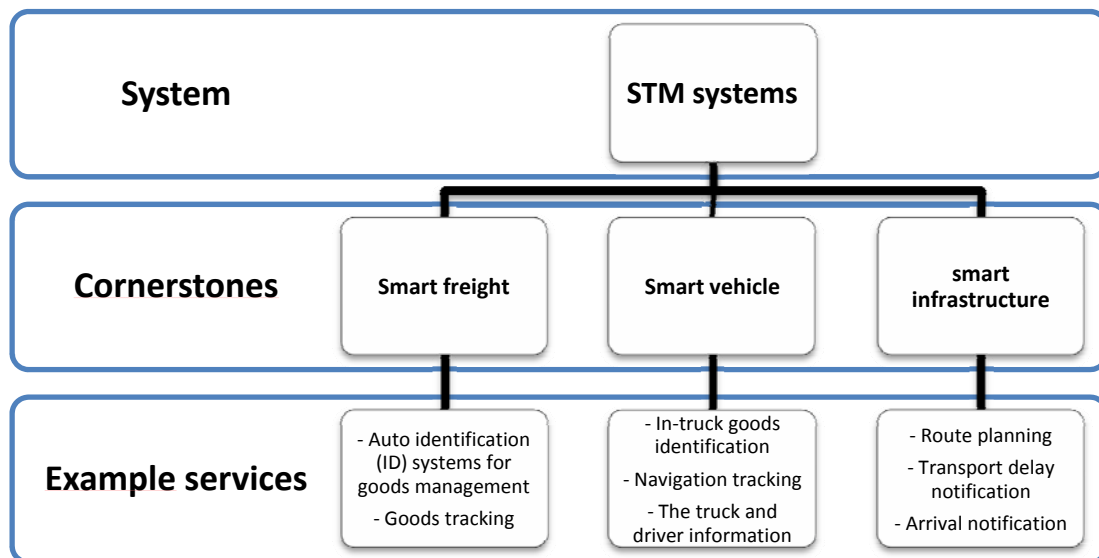


Figure 4- The elements of the STM systems and their example services

STM systems and value-adding SCITs

The STM systems are using different technologies as tools to increase visibility of information that is valuable for actors in the supply chain. Such systems support different types of decision regarding the supply chain operations by sharing such information and making it visible. As introduced in the previous chapters there are different types of information systems that partners of the supply chain are taking advantage of them for increasing the consistency between the flow of information and material (Lumsden 2006, Stefansson 2004).

In different studies effects of different types of information on the visibility of the supply chain information types are evaluated. For example Johansson and Pålsson has identified correlations between sharing different supply chain information after using the smart goods on the performance measurements of a supply chain or a logistics system (Johansson and Pålsson, 2009). Meyer et. al. 2009 has identified different values created by using the smart goods that increase visibility of the information for different partners of the supply chain (Meyer et. al. 2009). According to that study some of the advantages created after using such systems are: improving the manufacturing planning and control; security; asset management; service and maintenance and product lifecycle management. A general overview of the Intelligent Transportation Systems is conducted by the Taylor, 2002. In that study different definitions of the ITS by different literature are introduced and potential benefits from emerging different ITS technologies are identified but there is not any concern on the information types that are supported by such systems.

INFORMATION GAP MODEL

The model for identification of the information gaps by using the STM systems in supply chains is illustrated on the figure 5. The information gap is the difference between the value

level of the SC information (loads on left side of the balance) and support level of the STM systems regarding the information (loads on the right side of the balance). The best situation happens when the value level of a special type of information for different actors of a supply chain equals to the level of support from the STM systems for the same information. In this condition the information gap is reduced or eliminated by using the STM systems and they are working effectively.

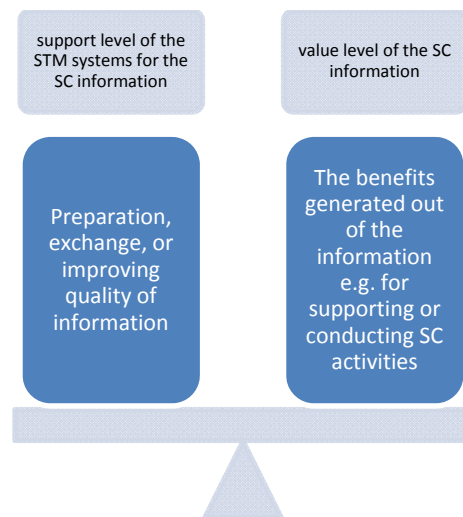


Figure 5- The information gap model in supply chain used for this study.

EMPIRICAL STUDY

The empirical study is conducted to show how the model for reducing the information gaps by using the STM systems could be applied.

For each information type for each of supply chain partner, the average values resulted from interviews are given. The data shows that different SC information types generate different levels of value for the partners of the supply chain. The partners of the supply chain interviewed are suppliers, manufacturers, logistics service providers, retailers and consumers (figure 1).

After considering the total level of value that these types of information generate for the supply chain partners, they are divided into three main groups. The first group (group I) contains the most valuable information type in a supply chain. The second group (group II) contains the information types that the level of their value is mediate. The third group (group III) are the information types which have the lowest value.

From the practitioner's point of view, warehouse operations information (Figure 5) is the most value adding information type. Most of the partners in the investigated supply chain are willing to acquire this real-time knowledge in their supply chain. Condition of the products, retailer's point-of-sale, location of the product, history of sales, available suppliers in the market and shipment quantity information are respectively the valuable information types in group II. Information about placement and sequencing of the products in inventory and shipment and available offers of the suppliers is the least beneficial information types from the practitioners' point of view according to this study.

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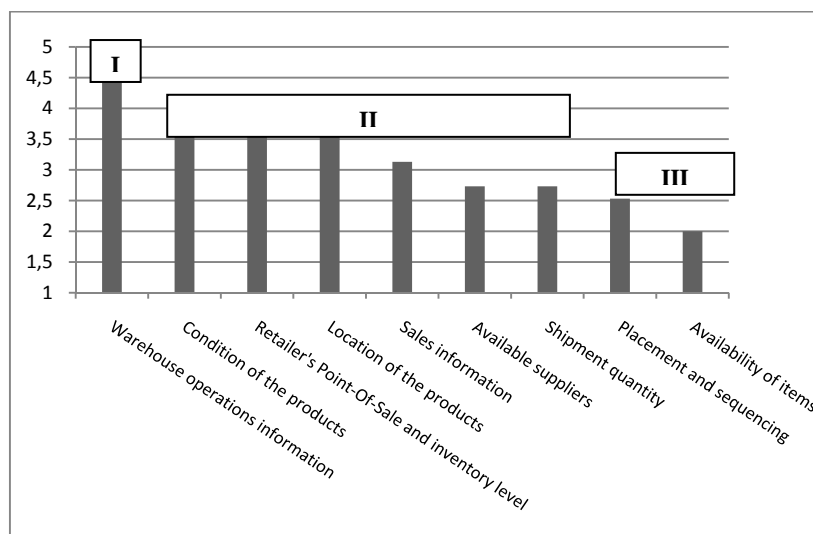


Figure 6- total value level of the supply chain information types for actors of the supply chain

According to the interviews, the SCITs are divided into three main groups based on the level of support they receive from the STM systems. This support could be in form of exchange, preparation or increasing quality dimensions of such information such as timeliness or accuracy of the information in the supply chain according to the used smart transportation system. These groups are illustrated on figure 7. Group I represents the information types that are supported the most by using the STM systems compared to other SCITs. As you see in the figure, the information regarding the location and the condition of the items in the supply chain shape this group, and the level of support for them is more than 3, indicating a level between the “mediate support” to “supportive.” Group II contains SCITs whose level of support is between 2 and 3, indicating a level between “a little support” and “mediate support.” Group III contains information types whose level of support is less than 2, meaning between “no support” and “a little support.” Information regarding the available items of companies and the sales information are the two information types that do not have a high level of support from the STM systems.

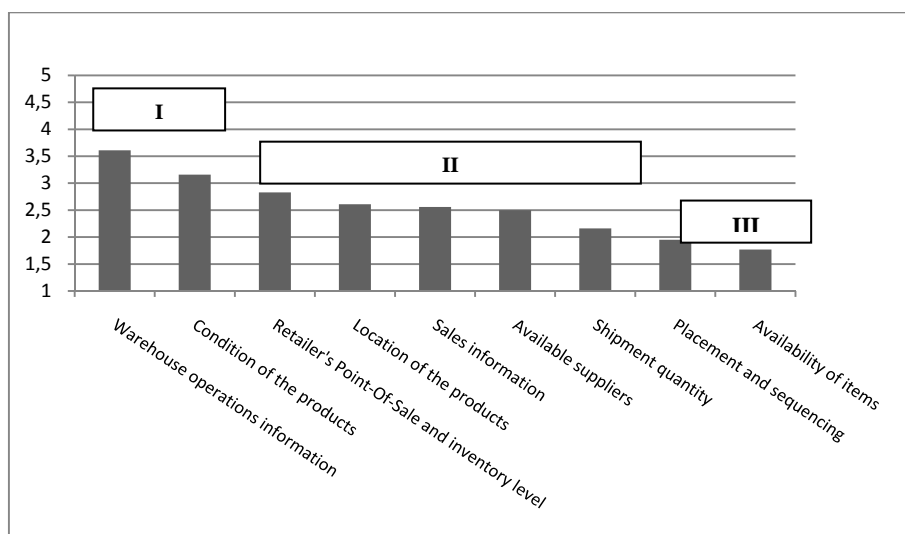


Figure 7- Support level for different SCITs from the STM systems.

ANALYSIS

According to the results of the two series of the empirical studies we can find out the supply chain information gaps by comparing the *value level* and the *support level* of the information types (Appendix 3).

Figure 8 is illustrating the value, support, and gap level for the same information types. As we see on the figure the largest gap is related to the warehouse operations information. It means that this type of information is much more valuable than the level of support it receives from the STM systems based on the conducted empirical study.

On the figure 8, the framework for identification of the information gaps in supply chain is tested for the STM systems generally including systems based on smart goods, smart vehicles and smart infrastructure. Also, the general supply chain information types (SCIT) are used for this gap measurement. The framework could be applied for the every supply chain based on the applied STM system(s) and the relevant valuable information types.

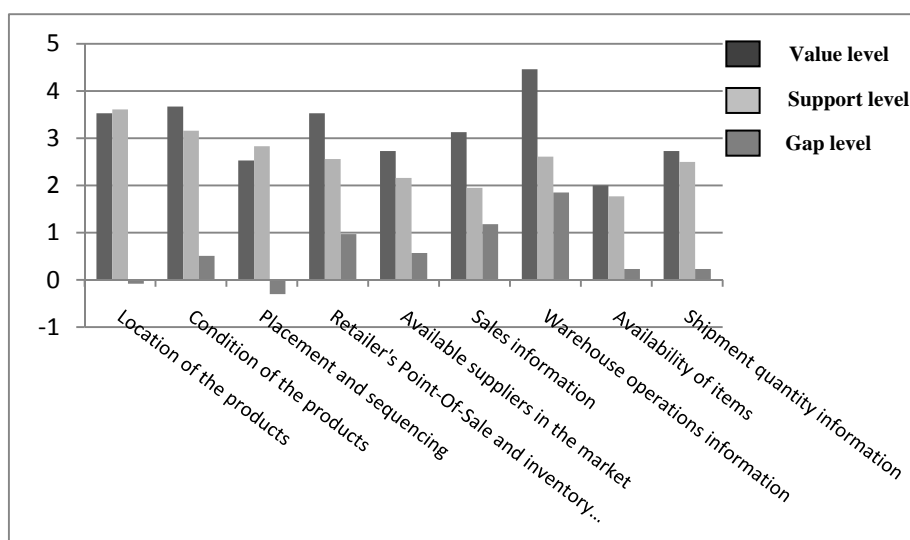


Figure 8- value level of information, support level received from the STM systems and concluded gap level.

On the figure 8, the framework for identification of the information gaps in supply chain is tested for the STM systems generally including systems based on smart goods, smart vehicles and smart infrastructure. Also, the general supply chain information types (SCIT) are used for this gap measurement. The framework could be applied for the every supply chain based on the applied STM system(s) and the relevant valuable information types.

According to the figure 8, for most of the information types there is a positive gap value. It means that based on the empirical study for most of the studied information types the level of value of the information is more than the level of support it receives from the STM systems. Location of the products in supply chain and placement and sequencing of the products in shipment and inventory are the two information types that the level of their support from the STM systems is more than their value for the supply chain actors.

Figure 9 is illustrating the supply chain information types on a 2 dimensional matrix. As shown on the figure the vertical axis is representing the support level or support level of the STM systems regarding different types of information and the horizontal axis is representing the value level of the information for actors of a supply chain. The area on the matrix is divided into four zones. The high-support-high-value (HSHV) zone; the low-support-high-

value (LSHV) zone; high-support-low-value (HSLV) zone; and low-support-low-value (LSLV) zone. The location of products and condition of products in the supply chain are the two information types in the supply chain that are located in the HSHV zone according to the empirical data. It means that the STM systems are performing efficiently regarding these two types of information in supply chain and such information systems are responding to the demand of the industry for supporting such information types. By reviewing documents of different companies that are producing STM systems and services, it is identified that a large number of such systems are working on supporting such information. Some of the STM services that are supporting the information related to location or condition of products in shipment and inventory are: goods tracking systems by using auto ID, in-truck goods identifications systems, arrival notification systems, navigation tracking systems, sensor-equipped goods that transmit real-time information regarding their physical attributes such as temperature, humidity, impact and so on.

The placement and sequencing of items, shipments quantity, available suppliers, and availability of items are four information types that are placed in the LSLV zone. The level of support that the STM systems are providing for such information is almost in the same low level of their value for the actors in supply chains. The third group of information are the sales information, warehouse operations and retailers' inventory level that are located in the LSHV zone. The STM systems are providing a level of support that is lower than the level of their value for the actors of the supply chains. This group of information types are concluded as the supply chain information gaps that are not supported appropriately by using the STM systems and therefore there is a need for developing the STM systems in a way that respond to this segment of the information for actors of the investigated supply chains of this study. Functions carried out by using such information could be named the function gaps that are not supported by application for the STM systems. Some of the functions correlated to such supply chain information types are illustrated on the table 1.

The dashed arrow illustrated on the figure 9 is representing an area that within it the level of value for the information is near to the level of support from the STM systems. This area is called the *Effectiveness Arrow*. It means that regarding the information types located within this area the STM systems are working efficiently and they support the information types in a level that is not more neither less than demands of the supply chain actors for it. Translation of this situation in real world is that investment on the STM systems for supporting the information types within the *Effectiveness Arrow* is reasonable.

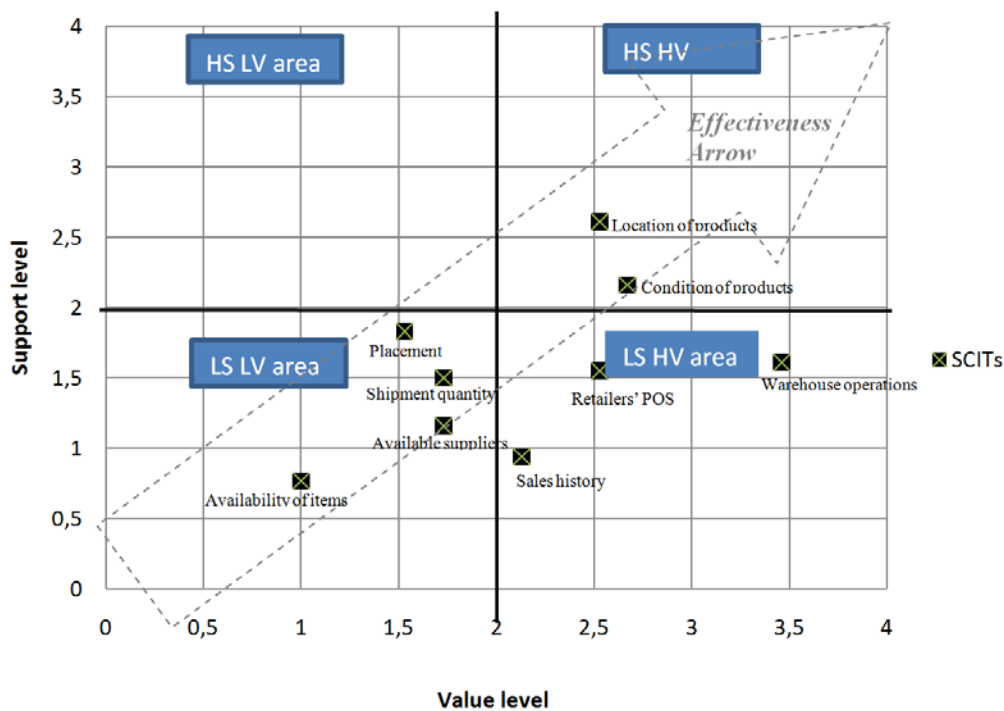


Figure 9- value level of the supply chain information types versus the support level they receive from the STM systems.

CONCLUSION AND FURTHER RESEARCH

Identification of the information gaps is needed as a primary step for reducing them in the supply chain. This identification is conducted by considering the demands of different actors for an information type and the level of benefit gained from that information type for all the actors in the supply chain. After identification of such gap, selecting suitable information systems can provide an effective solution. Making such decision demands deep knowledge about supportiveness of the information system regarding the needed information type and the costs related to implementation, education and operations of such information system.

The valuable information types are variable for different supply chains depending on the type of items and structure of the supply chain network.

The result of this study is useful for information operators of companies to identify the information gaps that could be reduced by using the STM systems. This paper is useful as a decision support for practitioners to develop the STM systems according to the value of the information that such systems support for actors of the supply chains.

Deep empirical studies in form of case studies or questionnaires filled by a large number of supply chain actors are needed to generate valid and applicable results regarding the actual level of gaps for different types of information in supply chains. It is an interesting suggestion for further research on this area.

In recent years attention of organizations to the environmental performance of their supply chains have increased dramatically. By increasing the variety of different services and

applications of the Smart Transportation Systems regarding decreasing the negative environmental aspects of transportation, study on the information types that create value regarding decreasing such negative factors seems necessary as a suggestion for the future research.

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