INTELLIGENT GOODS IN THE INTERMODAL FREIGHT SYSTEM

Astrid Bjørgen Sund, Trond Foss, Ottar Bakås
SINTEF Technology and Society

KEYWORDS
Intelligent goods, freight, intermodal logistics network, information exchange

ABSTRACT

Freight systems involve activities and actors from many different sectors in the field of logistics and transport. Information exchanged between the actors is often based on manual updating and handling of information. Implementation of intelligent goods, where the goods finds the most efficient way through the supply chain, will enable seamless interconnectivity between actors and activities in the intermodal freight system. Intelligent goods will make more effective transfer and provide a basis for improved collaboration between the actors in the logistics network, make intermodal transport more reliable and further create a potential for improving efficiency through better information quality.

Based on a literature review and interaction with industrial partners within the freight and logistics domain, the paper is oriented towards adoption and development of intelligent goods in multimodal freight systems. Collaboration have been made with a large number of organizations involving representatives from rail operators, forwarders, freight customers, transport authorities and suppliers of IT related equipment. By on-site registration and through interviews with the freight customer and the freight forwarder some challenges with intermodal freight were identified.

The paper reports on some of the findings from the INTRANS project focusing on how intelligent goods may support and enable seamless interconnectivity between the actors and activities in the transport systems including the terminal, make more effective container transfer in the intermodal transport network, provide a basis for improved collaboration between the actors in the logistics network and make intermodal transport more reliable from the sender to the receiver.

1. INTRODUCTION

Global competition in logistics and transport services and a focus on environmental friendly transport has lead to an increased attention to intermodal transport (Netland and Spjelkavik, 2009). The European Union has put transport as one of its strategic priorities, and it is clearly communicated in their transport policy that intermodal transport is a preferred alternative to road transport.

To meet environmental challenges and mobility requirements, the European Union has developed a strategy to support the advance of sustainable transport systems. The strategy promotes intermodal transport instead of unimodal road transport to shippers, forwarding companies and public authorities. The aim is to extend the intermodal network system in Europe and to remove barriers for using intermodal transport (van Klink and van den Berg, 1998, Woxenius and Bärthel, 2008). In the EUs white paper (2011) the interface between long distances and last-mile freight transport is highlighted. Intelligent Transport Systems (ITS) will contribute to real time traffic management, reducing delivery times and congestion for last mile distribution.

Intermodal freight systems are more complex than unimodal road transport systems, and thus require a larger range of planning activities. The complex structure and organisation of the activities in an intermodal chain requires longer lead time, collaboration of different actors, shipments and cargo units. Information exchanged in value chains is still reliant on a large degree of manual handling and updating. Due to all the actors which take part in performing intermodal transport, the interchange between the legs are crucial for making intermodal transport a success. The demand for more advanced transport and logistics services for supporting information sharing and collaboration between actors in the logistics network will increase (Stokland and Sund, 2010).

By the emerging concept of *intelligent goods*, the interchange between transport legs may be easier to achieve. Intelligent goods involve technologies for goods identification, sensors tracking status of goods status, and intelligence with embedded logic. Intelligent goods can be particularly promising for improving information flows and coordination in intermodal transports.

The application of intelligent goods will increase the available information about the location and the status of goods within a supply chain. This can result in an improved ability to track, trace, and monitor goods or the transport means carrying the goods. In the long term, more accurate or detailed information about freight, processed by optimization and control models, can lead to more effective use of people, equipment or infrastructure. The intelligent goods concept can be applied on several levels – ranging from individual item level, via package and pallet level, up to containers or other transport units. In this paper, we have chosen to focus on use of intelligent goods on the container level.

The purpose of this paper is to describe and analyze how intelligent goods may support and increase intermodal freight by improved interaction between actors and systems, and in that way make intermodal transport a real alternative to “door to door” road transport for goods owners.

2. RESEARCH METHODOLOGY

2.1 Case Study Approach

This paper presents findings and analyses from three Scandinavian research projects. Common for all the projects is that they study value chains where intermodal transport is used between the sender and the receiver.

The methodology employed in the paper is a case study approach. A case study is "an empirical enquiry that investigates a contemporary phenomenon within its real-life context and in which multiple sources of evidence is used" (Yin, 1989, p. 23). A study of intelligent goods in intermodal freight is a highly contemporary phenomenon which requires in-depth dialogue with the actors in an intermodal transport chain. Further, using multiple data sources was essential for the researchers in order to achieve full insight of the research problem. The researchers have studied relevant literature, collected secondary information sources, and involved industry representatives in workshops.

Based on a literature review and interaction with industrial partners within the freight and logistics domain, the paper is oriented towards adoption and development of intelligent goods in freight systems. Collaboration have been made with representatives from a large number of organizations involving representatives from rail operators, forwarders, freight customer, authorities and suppliers of IT related equipment. By on-site registrations and through interviews with the freight customer and the freight forwarder some challenges with intermodal freight were identified. The challenges were further examined during workshops with participants from the transport industry and academia.

INTRANS, INTERSYS and PROFIT are research projects in Scandinavia that are focusing on intermodal transport and main contribution to this paper. They are all research projects within the SMARTRANS program, a large research program for commercial industry transport and intelligent transport systems funded by the Norwegian Research Council. Common for these projects are that the consortium partners represent relevant actors in the study; transport users from the pharmacy and grocery industry, transport providers representing multiple transport modes, ITS technology providers and governmental infrastructure owners for road, rail and ports. The users have been actively involved in presenting current challenges, hosting use cases and validating results from the project. A brief presentation of the three projects is given below, describing their relevance to intelligent goods.

The overall objective of the **INTRANS** (Intelligent Goods in Transport Systems) project is to develop knowledge and systems for intelligent and automated flow of goods and information in transport systems through employment of leading-edge technologies like tracking systems and cargo sensors, to improve the efficiency of goods movement. The vision of the project is to enable a fully automated, multimodal and environmentally friendly freight transport system, where the goods itself finds the most efficient way through the supply chain, based on information and communication technology, and advanced control models and decision support (www.sintef.no/intrans).

The **INTERSYS** project has been running for almost three years, creating an opportunity for the involved researchers to get a thorough insight to the area of RFID in intermodal freight transport. It has given an opportunity to closely study the development of information transfer and intelligent transport systems in terms of evaluating the potential integration of tracking and tracing technology within intermodal freight transport (Pahlèn *et al.*, 2010).

The aim of the **PROFIT** project is to develop efficient intermodal terminals through improved collaboration between ports, carriers, terminals and forwarders. Collaboration between autonomous companies to solve collective problems is at best challenging because of the companies' different aims and ranking of priorities, non-compatible software, and unclear guidelines on dividing profit and risk. The terminal is only a small part of the different companies operating range, but the whole network is depended on an efficient terminal to maximize their competitive ability (www.sintef.no/Projectweb/profit/english-summary/).

In addition there has been interaction with other projects with similar focus. An example of this is the adoption of the ARKTRANS/FREIGHTWISE reference framework (Arktrans 2009). Based on the experience of the EU project FREIGHTWISE and its successor E-FREIGHT (www.efreightproject.eu) a structure for describing intermodal freight is adopted.

2.2 Case Description

Our use case company is a large wholesale and retail chain that operates food stores in Scandinavia. The company cooperates with a freight forwarder, which is one of the five forwarders dominating the inland freight market in Scandinavia. A process mapping of the transport chain of the case company was undertaken in the INTERSYS project. The information flow and the goods flow were mapped from the transport user through the main transport legs including the distribution part at the start terminal and the end terminal.

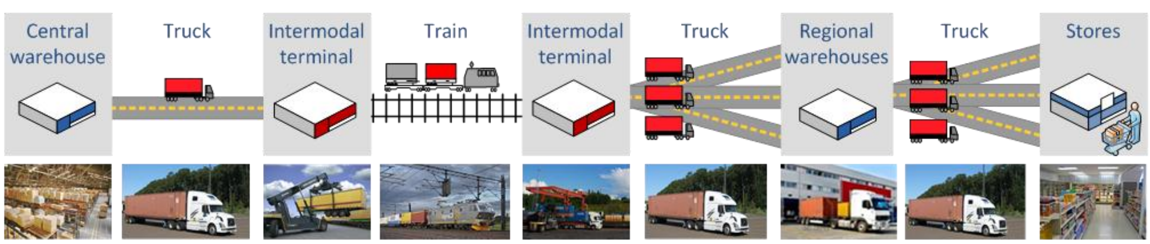

Figure 1: The transport chain of the use case company

The case company wants to use rail as much as possible, and even more than at present. However the company has experienced that reliability and predictability when using rail is not good enough. The average frequency of schedule deviations for cargo trains is twice a week. The deviation can vary from 2 hours to 2 days. When the container leaves the central warehouse each container has its own identification number. The regional warehouse receives a prior notice by email when the containers are loaded on the train at the intermodal terminal. If some of the containers are more urgent, the freight forwarder is supposed to know which ones, and give these containers priority for the transfer from the regional terminal to the receiver. The first truck which arrives from the intermodal terminal to the regional warehouse brings an envelope with the consignment notes. In this way the transport user gets information about which containers are shortly arriving the regional warehouse.

One of the challenges for the retailing company when using rail, is lack of up-to-date information on deviations from the expected arrival time. This creates difficulties in subsequent steps of the transport chain. It may in fact take several hours from a delay occurrence on the railway, until the receiver gets this information. This in contrast to a transport solution where trucks are used all the way from a central warehouse to regional destinations. In those situations, drivers will nearly always inform the customer by mobile phone if deviations occur.

3. THEORETICAL FRAMEWORK

3.1 Intelligent Goods and Smart Containers

The intelligent goods concept includes technologies for goods identification, status monitoring with sensors, and embedded logic (e.g. software agents), as well as communication with its surroundings through wireless and mobile technologies.

The concept has been denoted by many names. These include intelligent cargo, intelligent goods, smart goods, and smart freight (EURIDICE, 2008; Stefansson and Lumsden, 2008; Holmqvist and Stefansson, 2006; Lumsden and Stefansson, 2007). The meaning of these denotations is not identical, and no unified denomination is in place. In this paper, the definition used in the INTRANS project is adopted, where intelligent goods is described as goods that "*can find its most efficient way through the supply chain, based on information and communication technology and advanced control models and decision support*" (INTRANS, 2008). This description is complementary to the definition applied in the EU-project EURIDICE, where intelligent goods is described as goods that can connect itself to logistics service providers, industrial users and authorities to exchange transport-related information and perform specific services whenever required along the transport chain (Paganelli, 2009).

The intelligent goods should have the following properties as suggested by Foss (2008):

- Carrying crucial <u>information about itself</u>, such as a unique identity, special characteristics (e.g. dangerous goods) and origin-destination data.
- Being able to store information <u>on events</u> that may have an impact on the goods itself (e.g. high temperatures), or information on major delays.

- Taking actions on events that have exceeded predefined limits, for example by sending an alarm in case the location of the goods is not in line with the planned route data.
- Enabling a more accessible and feasible track and trace of the goods for actors involved in the value chain.
- Providing information to the control systems managing the transport of the items, by giving priority to certain types of goods in vulnerable parts of the transport systems (e.g. road and rail tunnels).

Research on intelligent goods look at how the goods should interact with each other and the transport systems, e.g. through electronic auction markets (McKelvey et al, 2009), agent-based communication support platforms (Dullaert et al, 2009) and standardized interfaces (Foss 2010).

The implementation of intelligent goods can enable access to real time information and better differentiation between goods concerning weight, size and number of goods. Here lies the potential for improving efficiency through better information quality. This paper focus on “smart containers”, which is the intelligent goods concept applied on containers. Smart containers are defined as containers that use sensors and systems for electronic tracking and reporting (adapted from Giermanski, 2008).

Jedermann and Lang (2007) have performed reduced scale prototypes with smart containers for the purpose of quality tracing and temperature logging in food chains. Their concept of smart containers maintains individual items inside the container, and links these items to one unified measurement of sensor data. By doing this, one can avoid high systems cost for equipping each item with an active sensor. But implementing smart containers for tracking in a supply chain required a high willingness for cooperation and sharing of information. If every partner in the supply chain optimises only his own profits and not the system, no one will win in the end (Jederman and Lang, 2007).

3.2 Smart Containers in Intermodal Freight Systems

Intermodal freight transport can compete with road transport only if the barriers to seamless interoperability are overcome. Transport users that are accustomed to using road transport have to be able to make modal shift without any negative consequences regarding price, reliability and associated services. Further the intermodal freight systems need to become more transparent so the customers may follow the goods on its way through the transport chain.

The core of an intermodal logistics network and the intelligent freight transport system is the intermodal terminal where material flows and logistics providers physically meet and transact (Goetz and Rodrigue, 1999; Woxenius and Bärthel, 2008; Netland and Spjelkavik, 2009; Stokland and Sund, 2010). The terminal is often the bridge between two different types of transport infrastructure and a place where many of the transport items are split in smaller units, sorted and merged again in new transport items. These processes will usually provide an easy access to the goods and its transport item. From an information viewpoint the terminals will probably be the crucial points for data collection and communication with the transport item. Terminal equipment will play a major role in the intelligent goods transport system. Terminal equipment covers both equipment used for moving goods within the boundaries of the terminal as well as the ICT systems that are installed at the terminal (Foss, 2008).

3.3 Loading Unit Level

The most convenient level for identification of goods in intermodal freight systems will be on the container or transport means level, i.e. the physical units being handled in intermodal transport. Information on individual goods items can be derived from other sources like SSCC (Serial Shipping Container Code), meaning that there is no need to identify these items individually during transport. SSCC is an identification key for an item of any composition established for transport and/or storage which needs to be managed through the supply chain (Pahlèn *et al.*, 2010, GS1 2011).

Due to the demands for identification of products and physical resources different levels for identification will be used. The main reasons for choosing one identification technology instead of another will be based on both costs and benefits generated by the chosen technologies (Pahlèn *et al*, 2010). The characteristic of the transport system and the goods itself decides which solution to use. The different alternatives are presented in Figure 2.

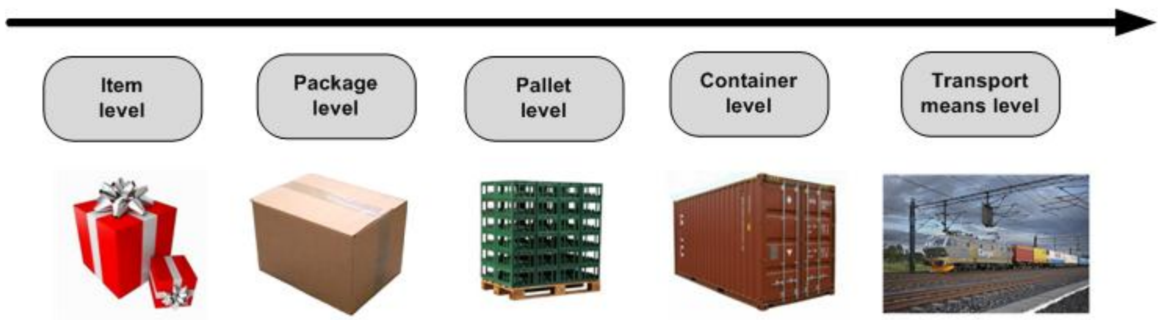

Figure 2: Unit level in the transport chain

The target for the identification in a supply chain can be the item, package, pallet, container or the transport means. Different tracking levels can be linked hierarchically to each other so that by reading the "highest level", all other items should identified (Permala and Scholliers, 2009). In that way the information on item or package level can be stored on pallet or container unit, simplifying the identification process and enabling different types of identifications and tracking technologies.

The lowest level for identification of goods in intermodal freight transport will be on container level, i.e the physical units being handled in intermodal transport. Individual items or pallets will not be handled in an intermodal freight system. Information on these two levels is above all relevant for freight transport where individual items and pallets are consolidated into larger shipments, i.e. before a freight transport can become intermodal.

Information on the individual goods items will be stored and nested to a hierarchical level where the information can be used, e.g. nested to the load unit or truck used for transporting the goods. In this way, information on the position and status of the goods can be communicated to the relevant stakeholders. Identification of the container level further increases the possibilities of using advanced identification and tracking technologies.

3.4 Foundation for Integration and Information Sharing across Actors

Advances in modern technologies for real-time data capture offers a wealth of opportunities for improved management, planning and control of logistics networks. In order to benefit from an intelligent goods system, a set of characteristics in the supply chain cooperation should be in place. Research done by Boeck and Wamba (2008) identified a set of dimensions that were found to be important antecedents that influence the result of information sharing through RFID in buyer-seller relationships: The following 8 dimensions should also be considered carefully with managers that pursue increased collaboration in their value chain: communication and information sharing, cooperation, trust, commitment, relationship value, power imbalance and interdependence, adaption, and conflicts.

The importance of information ownership does not appear clearly from this list but should not be disregarded. When introducing management systems based on intelligent goods across partners, there are some vital questions to address: Who owns the data, where is the data stored, how will they be shared across partners, and is payment required to access different levels of detail in the data?

For actors that are able to create high scores on these factors, all related to degree of supply chain integration between actors, there can be a larger probability for benefiting from employing intelligent goods.

3.5 Summary of theoretical framework

The theoretical framework is summarized in Figure 3. It shows that the implementation of intelligent goods can be analysed in three dimensions. The x-axis shows the degree of “intelligence”, defined by its functionality, for the intelligent goods. The y-axis shows the degree of integration between actors. The degree of integration can be analysed according to eight factors influencing integrations: communication and information sharing, cooperation, trust, commitment, relationship value, power imbalance (interdependence), adaption, conflicts and data ownership. The z-axis is defining what level of analysis that is studied, ranging from transport means level, down to the individual item level.

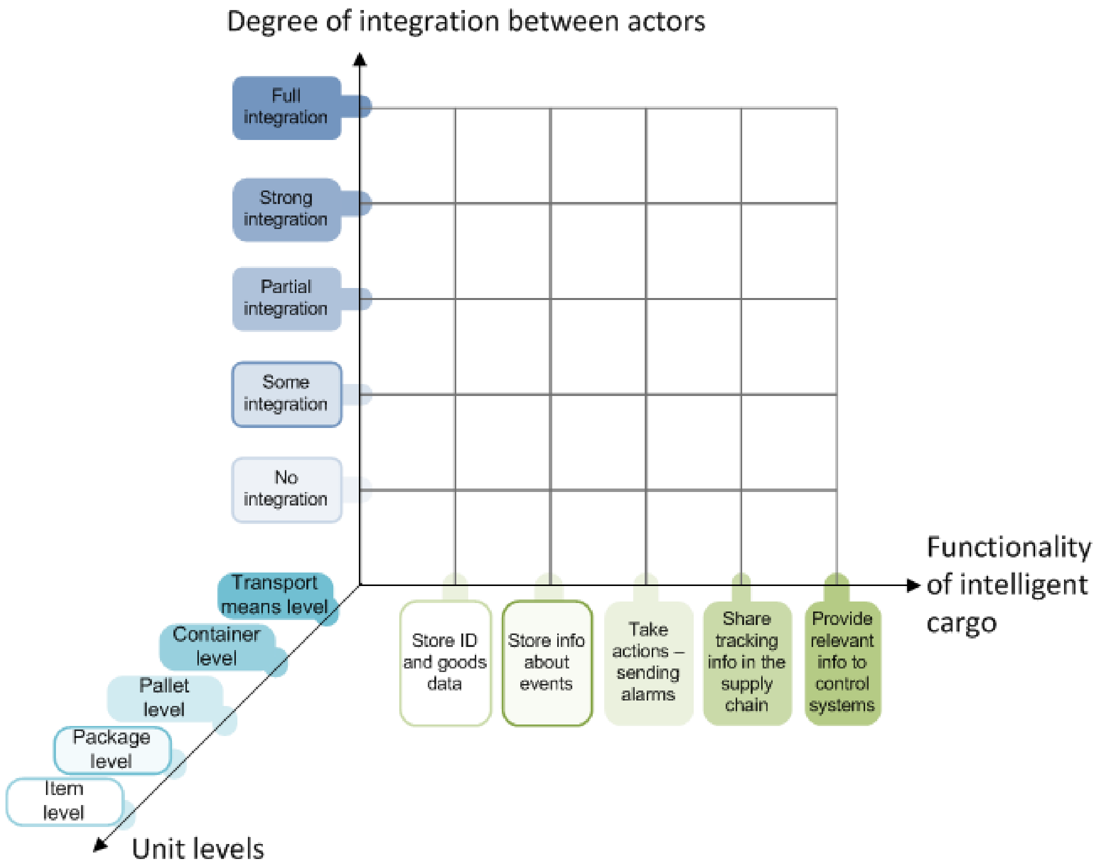

Figure 3: Theoretical framework for intelligent goods in intermodal transport.

4. DISCUSSION

4.1 The company case in the ARKTRANS framework

Based on interaction with stakeholders within the freight and logistics domain, some challenges related to intermodal freight were identified concerning adoption and development of intelligent goods. The challenges concerning information exchange and sharing was identified throughout the research projects described previously in chapter 2. The company case was modelled in the ARKTRANS framework, followed by a description of possible improvements with intelligent goods for the case company. ARKTRANS is the national framework architecture for multimodal intelligent transportation systems (ITS) in Norway. (Natvik and Westerheim 2008). ARKTRANS offers a generic view of the freight transport sector and harmonized specifications for transport services and operations. The transport sector is divided in 5 domains where each domain is build on a group of roles that are either functional and/or organizational closely linked to each other, see Figure 4.

The Transport User in the Transport Demand domain is responsible for defining the transport demand, in other words the role that has a need for a transport service, e.g. a product producer who wants to distribute his products to the retailers. The case company is a typical example on a Transport User having defined a transport need for transport of goods between the central and regional warehouse.

The Transport Supply covers the group of roles related to the provision of the transport service. Three of the dominant roles are Transport Service Manager, Transport Operation Manager and the Driver of the transport means. The Transport Service Manager is responsible for the planning of the services offered, the public information, the customer (Transport User) relationships and the delegation of the fulfillment of the transport needs to the Transport Operation Manager.

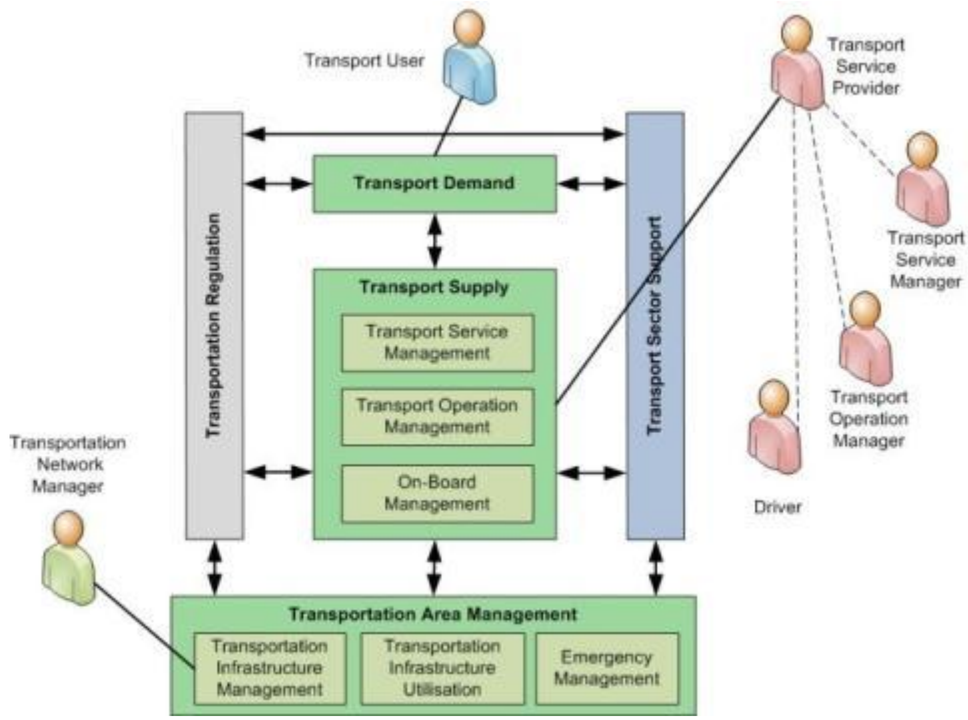

Figure 4: The ARKTRANS system architecture and the case study

The Transport Operation Manager is responsible for transport service planning and execution including monitoring of the transport items (goods) being transported in the infrastructure network. The freight forwarders are examples on both Transport Service Manager and Transport Operation Manager as they fulfil both roles. The Driver is responsible for driving the transport means based on the instructions from Transport Operation Manager and is also responsible for reporting back to the Transport Operation Manager. A common word for all roles in the Transport Supply domain is *Transport Service Provider*.

The Transportation Area Management domain covers the group of roles related to the management and operation of the transportation networks including terminals. In this case the Norwegian National Rail Administration) was fulfilling the role of the Transportation Network Manager.

The application of the ARKTRANS framework shows that intermodal freight transport is a heterogeneous process where each individual supply chain is unique and there are many different interfaces between the different roles. This means that standardisation of information and administrative processes have to be started from a very basic level. However, provided that the communication process and the exchange of information can be improved, there is a large potential for saving both time and resources

4.2 Improving communication of train and freight information to customers

In the case studies the use case company has been defined as a Transport User in the ARKTRANS framework. The freight forwarder and train operator are the Transport Service Providers and the rail administration is the Transportation Network Manager.

Figure 5 shows a simplified view of the information flows as they are today. Transport Service provider A (the rail transport provider) depends on information from the rail infrastructure owner concerning the infrastructure status and train delays. The Transport Service Provider B, having purchased the rail transport service from Transport Service Provider A, depends on the information from the Transport Service Provider A concerning information about the location and status of the load units (containers) in the intermodal transport network. Finally, the Transport User depends on information from the Transport Service Provider B concerning information about the location and status of the load units (containers) in the intermodal transport network.

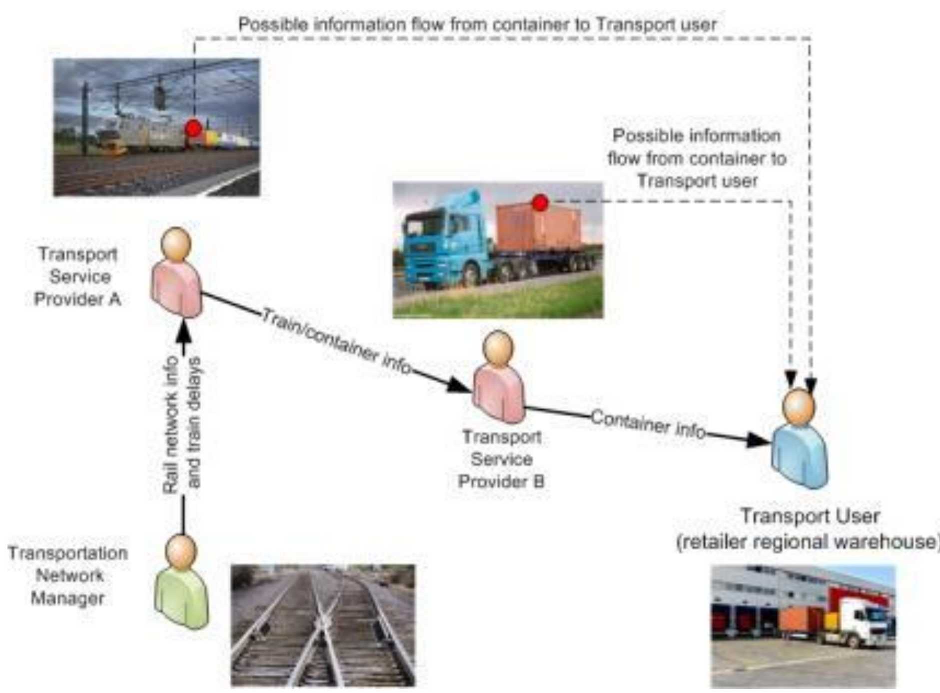

Figure 5: Existing and possible direct information flows

The introduction and implementation of intelligent goods, in this case smart containers, enables the Transport User to have direct information flow from the smart containers in the intermodal network wherever it is and whenever requested. The information sent directly to the Transport User could for instance be location information, any deviation from the planned schedule and status information, e.g. an alarm on too high or too low temperature in the container. The information could be very useful for the management of the loading/unloading and storing activities at the regional warehouse. Also the Transport Service Provider B in the use case would benefit from having the information directly from the container and not only through the Transport Service Provider A. The information could be very useful for the Transport Service Provider B concerning the management of his transport operations.

4.3 The theoretical framework applied at the use case company

The use case company is currently able to store ID and goods data, and has some integration with central partners and actors. The AS-IS situation for the case company in terms of employment of intermodal transport, and the desired TO-BE position is illustrated in Figure 6 by employing the framework from chapter 3.5.

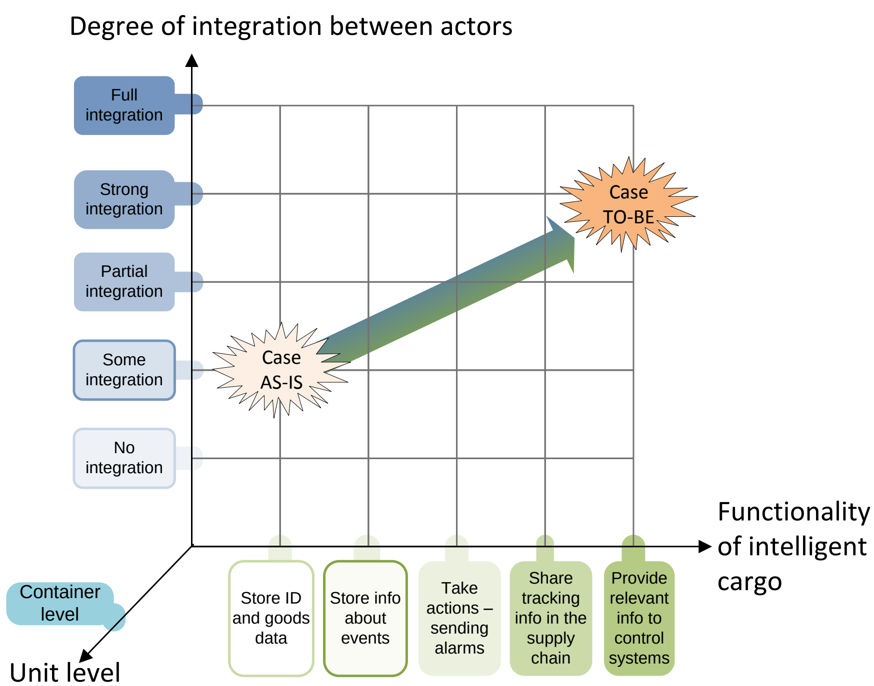

Figure 6: Use case company placed in the theoretical framework

By employing intelligent goods and receiving updated status information from containers, the use case company can be able to get notifications when deviations occur. By receiving alarms in case of unexpected events or when goods have been inactive for a long period, the company can better take actions and be proactive in their management of the flow of goods from central warehouse to the regional distribution centres.

4.4 Improving IT-system interconnectivity and information sharing

Interoperable information systems will be the information backbone of the transport systems for goods. The main responsibility of the interoperable information systems will be to provide a seamless and secure exchange of data and access to data for all involved actors (Foss, 2008).

An intelligent tag (e.g. RFID) on a container will be a very important object in the information system as it carries information that is crucial for several of the roles in the intermodal transport system. Via the access points in the systems, e.g. roadside equipment and entrances and gates at a container terminal, the information carried by the intelligent tag on the load unit is communicated to the involved roles. In the same way the involved roles are able to write information to the tag (requires a certain level of intelligent tag functionality) and in that respect the intelligent tag becomes an important hub in the interconnected IT-systems and it will also to a large extent improve the information sharing in general.

The interface between the access points and the intelligent tag has to be standardised, e.g. as described in Foss (2010). Even if the different IT-systems operated by the different roles are not interoperable on the technical and functional level, the compulsory interface related to the intelligent tag enables the different IT-systems to become interoperable concerning the information exchanged via the intelligent tag.

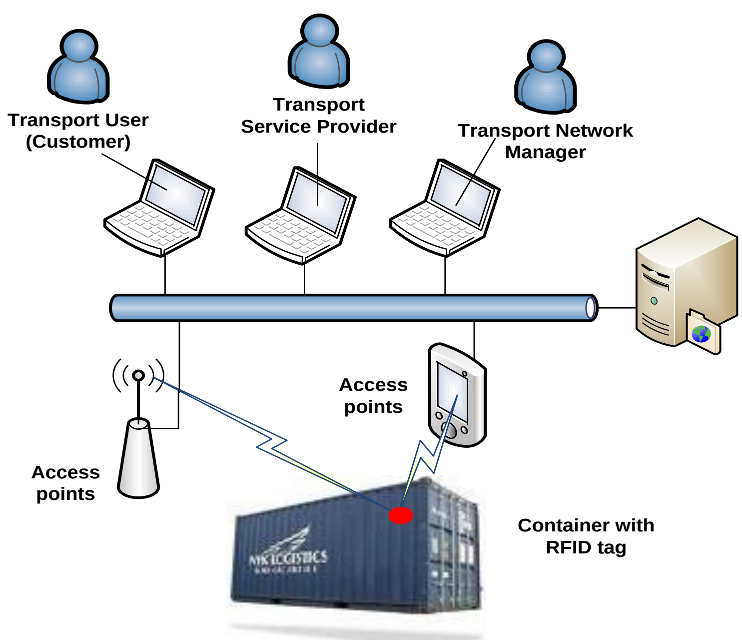

Figure 7: Information sharing in intermodal transport

For the Transport User the use of intelligent goods would be of high importance as it would facilitate a much better tool for track and trace as well as exchange of important information about the goods (the load unit) and its status. The intelligent goods could link the proprietary IT-systems used for the operation of their own supply chain management and transport systems with other ‘external’ IT-systems.

4.5 Potential impact on services

Improved data quality and information access in the transport chain can provide a list of improvements for developing new services for the involved actors. Below is a list of potential improvements for some of the major roles:

For Transport Service Providers:

- New systems enabling management of containers and vehicles
- Coordinating deliveries to end customer from multiple suppliers
- Localisation of all the transport provider’s equipment (e.g. vehicles, trailers, containers)
- Common framework for interoperable systems across transport modes

The Transport Service Providers can strengthen their competitiveness by being able to provide their customers (transport users) with improved services. The intelligent goods can make transport companies able to give precise information on arrival of their goods, and notifications when incidents occur. Further, they can improve their own operational efficiency by developing better routing and guidance systems to drivers, that consider real-time events from other actors in the supply chain.

For Transport Users:

- Reliable tracking of all goods in the supply chain
- Better estimates for transport and arrival times for containers
- Flexible transport solutions across different transport modes and service providers
- Decision support systems based on real-time status from containers
- Offering end customers more environmentally friendly transport of containers.

The Transport User can improve their own business models by providing end customers with better information about arrival of goods. They can also differentiate pricing policies and offer more environmental friendly transport solutions. Further, internal planning procedures of production and shipment can be improved by having decisions support systems that are fed with information about location and status of goods in transit.

Transportation Network Manager:

- Management of individual vehicles in transport systems based on detailed status information from the containers
- Smart capacity utilisation based on priority to individual vehicles with special needs

- Offering end customers more environmental friendly transport of goods.
- Statistics for experience data for assements and new measures.

The Transportation Network Managers, often fulfilled by governmental bodies, can also benefit largely from intelligent goods. Data gathered from intelligent goods can enable Transportation Network Managers to better manage individual transport means in urban areas based on detailed status information from the goods. This can benefit management of transports with dangerous goods, and can be used to give priority to such vehicles. Information from the goods can also be important in periods with congestion, and can be used to guide vehicles to less congested routes. A more detailed data capture from real-time traffic can enable Transportation Network Managers to analyse current status and provides better measurement data for performance analysis of the infrastructure utilization.

Relevance of the ARKTRANS framework

With several stakeholders in the intermodal logistics network application of the ARKTRANS framework makes it easier to see how intelligent goods may support transport in the intermodal chain and how this will have an impact on business models. The characteristics of the transport system and the many actors and roles involved mean that a modelling of an intermodal freight transport system becomes a complex process. The cost and complexity of setting up an information infrastructure for intelligent goods is often beyond the scope of private companies and organisations. In terms of cost savings and efficiency there are also doubts whether a future investment can be made profitable. There are certainly actors that may benefit from intelligent goods and therefore could be able to make the investment, but then there is a risk that the chosen solution could not be used by other actors further down the supply chain.

In Norway a national ICT infrastructure has been discussed where the national transport administration should take a leading role, using passive intelligent tag for tracking rail cars. This is an example of a nested solution where other actors in the transport chain could benefit from the information provided, given that the terminal operator gets involved storing additional information on the tag as the load unit is loaded or unloaded.

5. CONCLUSION

Implementation of intelligent goods will enable seamless interconnectivity between actors and activities in the intermodal freight system by making more effective transfer and provide a basis for improved collaboration in the logistics network. The paper describes how intelligent goods may support transport in the intermodal chain and how this will have an impact on services offered by different types of actors. Intermodal transport is like a relay race where each leg depends on the previous. The individual operator's role in the intermodal logistics network is to facilitate the next leg for the next Transport Service Provider.

Intelligent goods will;

- support and enable seamless interconnectivity between the actors and activities in the transport systems including the terminal.
- make more effective container transfer in the intermodal transport network
- provide a basis for improved collaboration between the actors in the logistics network
- make intermodal transport more reliable from the sender to the receiver.

Future research should involve an extended study of the intermodal freight transport system regarding the information handling and efficient sharing of information. Specifically this research should involve the role and functions of the intermodal terminal where the major part of the handling is made. In many ways, the terminal has proven to be the core of the intermodal freight transport system and the node for the information system. Further communication between the different stakeholders is crucial to the competitiveness of the intermodal freight transport in relation to other transport modes. Increased transparency throughout the supply chain, involving the transport operators, will become more important as the production systems in the future become more agile and lean. Future research should therefore focus on the terminal systems and their ability to support intermodal freight transport.

From the perspective of the intermodal operators, an information system owned and operated by the public authorities might constitute a threat according to the competitive situation and ownership of information. This means that some of the operators will be unwilling to share information, at least in a start-up phase. Future research and development have to further investigate in what way the control and ownership of an intelligent infrastructure will influence the use and value of such a system.

Due to the complexity of intermodal freight transport, the research and development process contains several steps and considerable effort. Future research should therefore involve both the development of theoretical models that will be able to describe the various relationships and dependencies of the intermodal freight transport system. For the competitive advantage of intermodal freight transport it is crucial that the system becomes more flexible and that the transparency of the transport system increases. Finally, future research should also include the ownership and responsibility for a future ICT infrastructure.

An important result of this paper is the application of the ARKTRANS framework to real cases in intermodal freight transport. The characteristics of the transport system and the many actors and roles involved mean that a representation of an intermodal freight transport system becomes a complex process. The ARKTRANS reference framework is a useful tool for describing the transport system from a case study perspective, there are few alternative models or frameworks being verified and proven useful in a real context.

6. REFERENCES

ARKTRANS (2009): “The multimodal ITS framework architecture, version 6. Authors Marit Natvig, Hans Westerheim, Tor Kjetil Moseng, Audun Vennesland, Børge Haugset, Geir Frode Skylstad. *SINTEF REPORT* A12001, 2009.

Boeck, H. & Wamba, S.F. (2008), “RFID and buyer-seller relationships in the retail supply chain”, *International Journal of Retail & Distribution Management*, Vol. 36 No. 6, pp. 433-460.

Dullaert, W., Neutens, T., Vanden Berghe, G., Vermeulen, T., Vernimmen, B., Witlox, F. (2009): An intelligent agent-based communication support platform for multimodal transport. Expert Systems with Applications 36 10280-10287.

European Commission White paper (2011): Roadmap to a single European Transport area.Towards a competitive and resource efficient transport system. Brussels COM 144 final.

EURIDICE (2008), WP 14, Deliverable D14.1: Preliminary User, System and Communication Services Definition, retrieved from: http://www.euridice-project.eu

Foss, T. (2010), “The integration of control systems for the supply chain and transportation domains”, *Proceedings of the 12th World Conference on Transport Research*, July 11-15 2010, Lisbon, Portugal.

Foss, T. (2008), “Intelligent Goods in Intelligent Transport Systems”, *Proceedings of the World Congress and Exhibition on Intelligent Transport Systems and Services*, New York.

Giermanski, J. (2008), “Tapping the Potential of Smart Containers”, *Supply Chain Management Review*, Jan/Feb 2008, pp. 38-44.

GS1 (2011), SSCC (Serial Shipping Container Code), webpage retrieved from http://www.gs1.org/barcodes/technical/idkeys/sscc

Holmqvist M, Stefansson G. (2006), “Smart Goods' and Mobile RFID-A Case With Innovation From Volvo”, *Journal of Business Logistics*, Vol. 27, No. 2.

INTRANS (2008), The INTRANS concept – intelligent goods in transport systems, presentation KMB Intrans, July 2008, available at: http://www.sintef.no/project/INTRANS/INTRANS%20Concept%20Final.pdf

Jedermann, R. & Lang, W. (2007), “Semi-passive RFID and beyond: steps towards automated quality tracing in the food chain”, *International Journal of Radio Frequency Identification Technology and Applications*, Vol. 1, No. 3, pp. 247-259.

Jevinger, Åse, Paul Davidsson,. Persson Jan A (2010) Agent Based Intelligent Goods, *Proceedings of 9th International Conference on Autonomous Agents and Multiagent Systems* (AAMAS 2010), Van der Hoek, Kaminka, Lespérance, Luck and Sen (eds.), May, 10–14, 2010, Toronto, Canada.

Lumsden, K. & Stefansson, G. (2007), “Smart freight to enhance control of supply chains”, *International Journal of Logistics Systems Management*, Vol. 3, No. 3, pp. 315-329

McKelvey, B., Wycisk, C., Hülsmann, M. (2009), “Designing an electronic auction market for complex 'smart parts' logistics: Options based on LeBaron's computational stock market”. *International Journal of Production Economics*, 120, pp. 476-494.

Natvig, M. & Westerheim, H. (2008), “Refinement and evaluation of the ARKTRANS framework through use in travel information services", *in proceedings of the 15th World Congress on Intelligent Transport Systems*, New York, USA 16-20 November 2008. Retrieved from: http://www.sintef.no/project/INTRANS/ARKTRANS-improved%20by%20MultiRIT-ITS%20World%202008-%20Natvig%20and%20Vennesland.pdf

Netland, T., and Spjelkavik, I. (2010), “Making PROFIT at the intermodal terminal – a research agenda”, in *proceedings of APMS conference* Advances in Production Management Systems. New Challenges, New Approaches, Bordeaux, France, 21.-23.09.2009, IFIP Advances in Information and Communication Technology, 2010, Springer Verlag, Volume 338/2010, pp. 307-314.

Pahlen, P.O. et al (2010): *RFID-support for identification and control of shipments, load units and wagons in intermodal transport systems*, INTERSYS final report, Göteborg, Sweden. Retrieved from: http://www.sintef.no/uploadpages/273231/Dokumenter/INTERSYS%20Final%20report.pdf

Paganelli, Paolo *et al.* (2009), EURIDICE white paper, version 1.0, 02.11.2009, The EURIDICE project - European Inter-Disciplinary research on Intelligent Cargo for efficient, safe and Environment-friendly logistics. Retrieved from: http://www.euridice-project.eu/index.php/web/pubdocs/58#

Permala and Scholliers, (2009). “Freight Transport Visibility Provided by RFID”, *Presented at the ITS World Conference, Stockholm*. Retrieved from: www.vtt.fi/inf/julkaisut/muut/2009/ITS_Stockholm_2009_final.pdf

Stafansson, G., Lumsden, K. (2008): “The Essentials of Smart Transportation Management”, *Proceedings of NOFOMA 2008*, Helsinki.

Stokland, Sund, Netland (2010), “Challenges in intermodal logistics networks and terminals”*, In the proceedings of the 12th World Conference on Transport Research WCTR, July 11-15, 2010 – Lisbon, Portugal,* available at: *http://www.civil.ist.utl.pt/wctr12_lisboa/WCTR_General/documents/01319.pdf*