THE INTEGRATION OF CONTROL SYSTEMS FOR THE SUPPLY CHAIN AND TRANSPORTATION DOMAINS

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ABSTRACT

This paper describes some of the results up till now of the research project INTRANS supported by the Research Council of Norway. The paper focuses on the results related to the integration of control systems in the Supply Chain (SC) domain and the transport domain. By control system in the SC domain is meant any system that supports the decision takings in the SC and by control system in the transport domain is meant any system that supports the monitoring and management of a transport network, e.g. a road network. The paper looks upon the integration from an interoperability point of view and describes the three different types of interoperability, Contractual, Functional and Technical interoperability, providing complete interoperability. The paper takes the role model and functions defined in the ARKTRANS – The Multimodal ITS framework architecture as the starting point and combines it with the Supply Chain Operations Reference (SCOR) model. The paper describes how complete interoperability can be achieved by a common role model for the two domains, a common set of core functions for the two domains and a common information architecture. The paper also introduces the intelligent goods as a crucial link between the two domains as well as playing an important role in the decision taking in the SC domain and the monitoring and management of transport in the transport domain. Finally the technical interoperability is described. The main objective of the paper is to propose a way forward to link and integrate the SC and transport domain for the benefit of the stakeholders in both domains concerning a more effective, secure and reliable transport of goods.

KEY WORDS

Interoperability, transport, supply chain, intelligent goods, role model, control system

INTRODUCTION

The supply chain and the transportation domain intersect whenever there is an item in a supply chain that shall be moved from one location to another. By a Supply Chain (SC) is in this paper meant two or more organisational units that are associated with each other by:

- A common policy and strategy for improving the competitiveness of the supply chain
- A Set of Rules for the operation of the SC (enabled by international and national laws and regulations, bilateral or multilateral agreements and/or SC specific regulations and specifications)
- Flows of information (enabled by information and communication network systems and services)
- Flows of goods or material (enabled by transport systems and services)
- Flows of payment information and payments (enabled by financial systems and services).

The organisational units may be organised in a sequential and/or parallel order. Supply Chain Management (SCM) is defined as the task of integrating organisational units along a supply chain and coordinating material, information and financial flows in order to fulfil (ultimate) customer demands with the aim of improving the competitiveness of a supply chain as a whole (Stadtler, H 2008).

The supply chain domain is in this paper defined as any collection of supply chains and their individual and integrated management. By transport domain is meant any collection of transport systems and its services and information flows, e.g. a road or a rail network with its terminals, used for the movement of persons and/or goods (Foss, T 2009).

This paper reports on the findings of the Norwegian research project INTRANS (Intelligent Goods in intelligent Transport systems). The main objective of INTRANS is to develop knowledge, concepts, models and systems for intelligent, fully-automated flow of goods and information in transport systems through employment of leading-edge technologies (INTRANS). This paper focuses on how the different actors in the SC and transport domain may benefit from a better integration of the two domains by sharing the information infrastructure and the information itself. The SC domain needs measures to optimise the supply chains and to control and monitor the transport of goods and materials in the transport links in the supply chain. The transport domain needs measures to plan the use of the transport systems and to control and monitor the movement of vehicles in the transport systems. Hence, the two domains could benefit from the utilisation of the information carried by the goods, materials and the vehicles while being stored/parked or being moved/moving in the transport systems. The utilisation of common information and communication networks and services requires interoperability on a contractual level defining the Set of rules for the interoperability between the two domains. Furthermore the intersection of the two domains requires interoperability on a functional and technical level. This paper focuses on the functional and technical level but the contractual level (Set of Rules) is also described to give a complete picture.

Figure 1 below gives a simplified overview of the intersection between the controlling, managing and monitoring systems in the two domains. The SCM system is connected to the three different transport systems shown in the figure. Each transport system represents one type of transport mode, e.g. a road network with vehicles or a rail network with trains. For simplicity reasons only one connection is shown for each of the transport systems but they may be multiple. The SCM is also connected to the nodes between the transport systems. The nodes can be between two transport systems of the same mode, e.g. an intersection between two road networks or it can be a terminal between two transport systems of different modes, e.g. a harbour connected to a road network. A node may even have its internal transport system, e.g. an Automated Guided Vehicle (AGV) system in a terminal. Each transport system may consist of multiple links and nodes but for simplicity reason this is not shown in the figure.

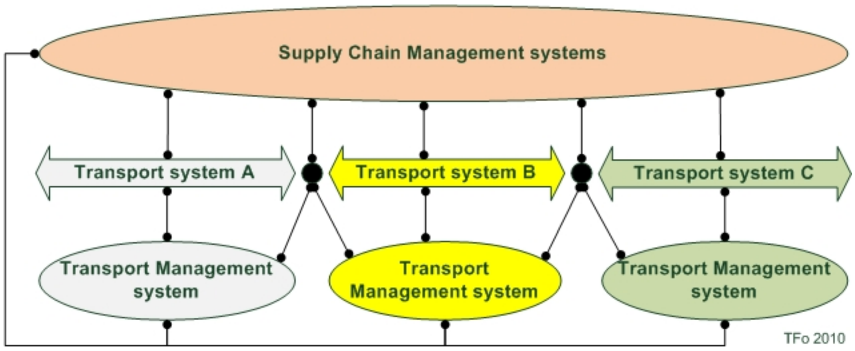

Figure 1: Overview of the intersection between the two domains

Transport Management Systems (TMS) are monitoring and managing the movement of vehicles in their respective transport systems. Only one monitoring/managing link is shown for each system but they may be multiple. All the TMS's and the SCM system are assumed to be inter-connected. Hence, the information between the SCM system and the TMS's may go directly between the systems or via the units transported in the transport systems including the nodes and/or the vehicles transporting them.

The main objective of the paper is to propose a way forward to link and integrate the SC and transport domain for the benefit of the stakeholders in both domains concerning a more effective, secure and reliable transport of goods. The proposed way forward is based on achieving interoperability by a common role model, common functions and information elements and the intelligent goods as a crucial bridge-building object between the SC and transport domain. This is done in the chapters Interoperability, Contractual interoperability, Functional interoperability and Technical interoperability. Finally it is described how the concept of intelligent goods can support some of the main functions/processes in control systems in the SC and transport domain.

METHODOLOGY

The following methodology has been applied for the INTRANS results presented in this paper:

- Investigation of available role models in the SC and transport domain searching for role models that were technology independent, internationally applied, stable and maintained and based on state-of-the-art, best practice and de facto or international standards
- Applying on the SC and transport domain the principle that interoperability between two or more systems is achieved via contractual, functional and technical interoperability
- Proposing a common role model based on the findings from the research on available role models providing the bases for contractual and functional interoperability
- Proposing a set of common and basic functions and data elements enabling functional interoperability
- Proposing a set of hierarchy of On-Goods Equipment (data carrier and communicator object fixed to the goods) and a set of interfaces between the different types of equipment enabling technical interoperability
- Proposing how the intelligent goods could support the control systems applications in the SC and transport domain
- Pointing on areas and issues where further research is needed

INTEROPERABILITY

Interoperability in relation to intelligent transport systems (ITS) is defined as the ability of two or more systems or components to exchange information and to use the information that has been exchanged (IEEE). The term interoperability is sometimes, e.g. in Electronic Fee Collection systems, divided into three different levels: contractual interoperability, functional interoperability and technical interoperability, see Figure 2.

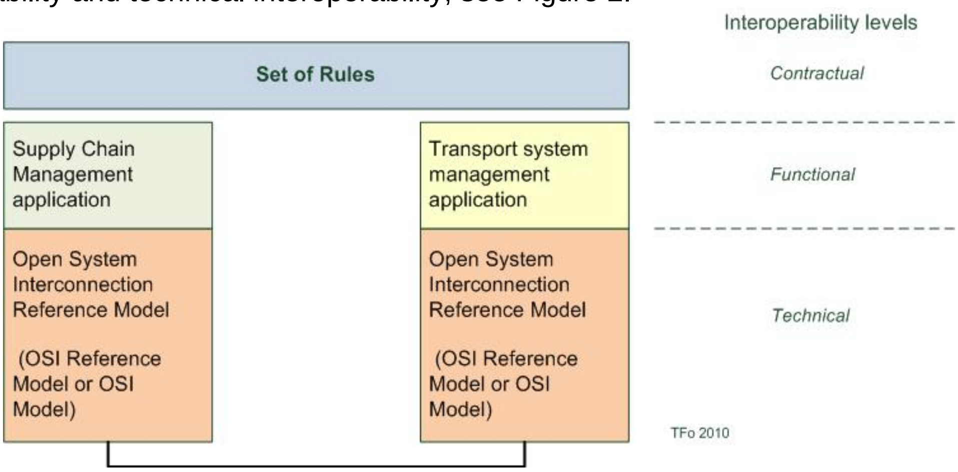

Figure 2: Overview of the interoperability levels

All levels have to be present in order to achieve complete interoperability and these levels have also been applied in the INTRANS research project.

Contractual interoperability is the highest level of interoperability. It defines the Set of Rules for the systems to be interoperable. The Set of Rules will cover important issues as commercial rules, ownership of information, functional and technical specifications, interoperability tests procedures, governing rules, arbitration rules and laws and regulations that the involved systems have to adhere to.

Functional interoperability implies that the functions and information in one system should be matched by the functions and information in the other system and vice versa. A very simple example will be if one system sends a control flow (command) to the other system requesting a specific data element, e.g. GET ATT-ID 127. The receiver of the GET should both understand the commando GET and the attribute ID 127. The response from the receiver, e.g. GET-RESPONS 20100122110534 should of course be understood by the sender of the control flow. Functional interoperability may also be called Semantic interoperability (Wikipedia A).

Technical interoperability implies that the systems involved are able to communicate. The communication services and ways of defining data transferred have to be the same on both sides of the physical interface between the systems. Technical interoperability is very often designed in compliance with the Open System Interconnection (OSI) reference model (X.200). The OSI model defines 7 layers where the Application layer is the highest level (closest to the user application) and the Physical layer is the lowest layer and defines the connection between two devices, e.g. two servers in a network or between an RFID tag and the tag reader/writer. Technical interoperability may also be called Syntactic interoperability (Wikipedia A).

CONTRACTUAL INTEROPERABILITY

Contractual interoperability is in this paper defined as the Set of Rules that defines the commercial, functional, technical, trust and security relationships between the actors involved in the integration of the SC domain and the transport domain. Both domains have already their own Set of Rules. The entities within a SC are connected to each other by a common policy and strategy, rules for the operation of the SC and flows of information, goods and materials and payments. To enforce the coherence of the SC actors several types of bonds may be used (Stadtler, H 2008):

- Technical bonds which are related to the technologies employed by the firms
- Knowledge bonds related to the parties' knowledge about their business
- Social bonds in the form of personal confidence
- Administrative bonds related to the administrative routines and procedures of the firms
- Legal bonds in the form of contracts between the firms

The transport domain also has its Set of Rules. As most publicly available transport systems are operated by public authorities or by private companies having a concession to do so, most of the Set of Rules are defined by international and national laws and regulations, Directives (in the European Union), international and national standards and/or specifications, public budgets and commercial rules and agreements for compensations and reimbursements for the provision of transport system infrastructure and transport systems operations and services, e.g. the operation of a rail network and the provision of rail services.

Although it could be challenging to achieve contractual interoperability between the SC domain and the transport domain it is a necessity. The necessity is especially caused by the integrated use of information. One of the main issues in information security is that there should always be a responsible owner of any piece of information floating or being stored in a system. The integrity of the information should be kept from source to sink and this is just one example that proves that there have to be some common and agreed rules when integrating the SC and transport domain.

For the integration of the SC domain and the transport domain the Set of Rules should include:

- Governing rules including arbitration rules and applicable laws and regulations
- Commercial rules that define how to share common costs for
  - establishment and maintenance of Set of Rules
  - information infrastructure (both investments and operation) used by both domains
  - information security and trust relationships
- Functional rules including roles and responsibilities definitions, application interface definitions including interoperability test specifications, information security including information ownership, confidentiality, integrity and availability. Most of the rules will be references to documents and specifications that have to be prepared as part of the functional interoperability.
- Technical rules for interfaces between equipment in the physical architecture being part of the integration of the two domains. The technical rules will first of all include references to the technical specifications and interoperability tests procedures for the interfaces that have to be prepared as part of the technical interoperability.

This paper will not go into further details in relation to the Contractual interoperability. However, the basis for the functional and technical rules will be further described later in this paper (Functional and Technical interoperability).

FUNCTIONAL INTEROPERABILITY

Functional interoperability is in this paper defined as the ability of two or more individually and independent systems to provide services to each other and to exchange information by implementing a common set of functions and information elements while assuming that all the involved systems are technical interoperable. The definitions found in the literature are more sector-oriented and narrower than the more general definition used in this paper.

An important part of the functional interoperability is the common role model being the fundament for the allocations of functions and information storage as well as defining the main interfaces. This paper will describe a role model that has been developed in the Norwegian research project INTRANS (INTRANS 2010). The role model (Foss, T 2009) again builds upon 1) the research project ARKTRANS (ARKTRANS 2010) which has developed a multimodal framework for Intelligent Transport Systems (ITS) and 2) the Supply Chain Operation Reference model (SCOR) developed by the Supply Chain Council (SCC 2010).

The functions of a system can be described by the responsibilities of the roles or by the processes that the system is performing fulfilling the objective(s) of the system. This paper proposes a set of common functions that could be used as part of the functional interoperability. The functions will be a kind of middleware between the OSI layer services and the SC domain and transport domain applications for the control systems. By middleware is meant a computer software that connects software components or applications.

The information architecture will also be described by proposing a set of crucial data elements needed for the middleware.

The role model

The term role model is in this paper defined to be an abstract model of the actors involved in the operation of a system and where each role represents a set of responsibilities that are organisationally, logically and functionally closely linked to each other. A *Producer* or *Manufacturer* in a SC could be one example of a role while a *Transport Service Provider* in a transport system could be another example. The SC literature has almost no references on role models for supply chains but there are numerous process models. One of the few references found was a conceptual role interaction model for SCM in Small and Medium Enterprises (SMEs) (Thakkar, J 2008). The paper defines various role players and logic for the quantification of a conceptual role model. However, the term role is used in a much wider sense than in this paper as it also covers more abstract issues like the roles of the market and competition, culture and competitiveness. The term role model is well known from the ICT terminology where Object Role Modelling (ORM) is defined as: A conceptual modelling approach that pictures the application world as a set of objects that play roles (parts in relationships, which may be unary, binary or higher order). ORM provides both graphical and textual languages that enable models to be expressed naturally (Webster).

The transport domain role model

The highest level of the ARKTRANS ITS framework is the Reference model that represents a division of the complex transport sector into a set of sub-domains that are manageable and provides an overall conceptual model of transport sector. Each of the sub-domains represents a set of roles where each role is defined by a set of responsibilities and a set of objects relevant and needed for describing and/or defining an intelligent transport system. A responsibility can only belong to one role and an actor (stakeholder) can fulfil one or more roles. One role belongs to one sub-domain only. The roles are seen as abstract entities and are independent of organisational issues and will persist through organisational changes. A role may be implemented by an organisation, by a (sub)system or by a person. Hence, the role model provides a very flexible and organisation- and technology-independent tool for describing any existing system as well as specifying any new system.

Figure 3 shows the ARKTRANS Reference model with its 5 sub-domains: Transportation Network Management, Transport Demand, Transport Service Management, On-Board Support and Control and Transport Sector support. The connections between the sub-domains illustrate possible control and information flows between the sub-domains and their roles.

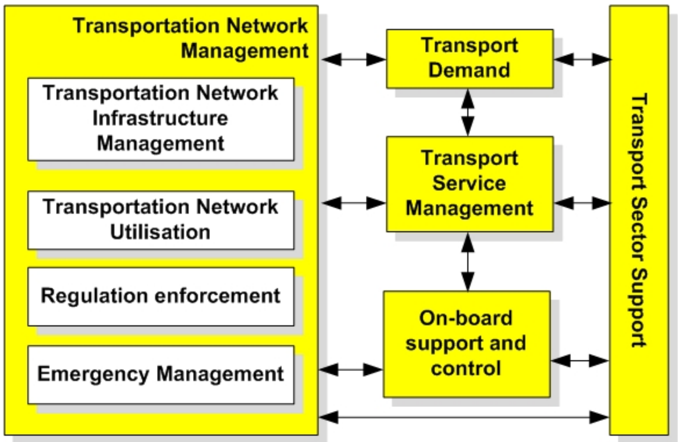

Figure 3: The ARKTRANS Reference Model (Source: ARKTRANS 2010)

The Transportation Network Infrastructure Management part of the Transportation Network Management covers the two roles *Transportation Network Manager* and *Transportation Network Operator*. Only the first one is seen as relevant for the integration of the SC and transport domain and the role is responsible for the physical Transportation Network infrastructure consisting of transport links and Transfer Nodes. The role is also responsible for the information about the physical Transportation network.

The Transport Network Utilisation covers four roles where three of them are relevant for this paper: 1) *Traffic and Transportation Planner*, 2) *Traffic Manager* and 3) *Traffic Network Resource Manager*. The first role is responsible for the strategically and tactical planning of traffic and transportation issues in an area. The second role is responsible for the management of the transport system including incident handling and provision of transport system status information and the third role is responsible for allocating network resources to the vehicles in the transport system, e.g. separate lanes for public transport buses and/or commercial vehicles. Of the roles described for the Transport Network Management the role called *Traffic manager* is probably the most significant role in relation to the integration of the SC and transport domain.

In the Transport Demand group of roles there are three roles but the most significant one for this paper is the *Transport User* which is a crucial role in the integration of the two domains as it is later described in this paper. The role of the *Transport User* is to define the transport demand, finding the best transport alternative, transport planning and perform the follow-up of the transport and eventually adjust the plans to incidents or changes in the circumstances or conditions.

The Transport Service Management covers three different roles where the role called *Transport Service Provider* is the most crucial one. The role is responsible for the provision of transport services to a *Transport User*, e.g. transport of materials from a plant to a factory. The role is also responsible for the management and execution of the required transport operations.

The Transport Execution Support and Control covers the role *Transportation Network User*, e.g. the driver of a truck. The role is first of all responsible for the operation and movement of the vehicle trough the transport system taking into account and adhering to the rules for the use of the transport system including transport and traffic regulations, safety and security.

Figure 4 shows the most relevant roles in the transport domain in relation to the integration of the SC and transport domain.

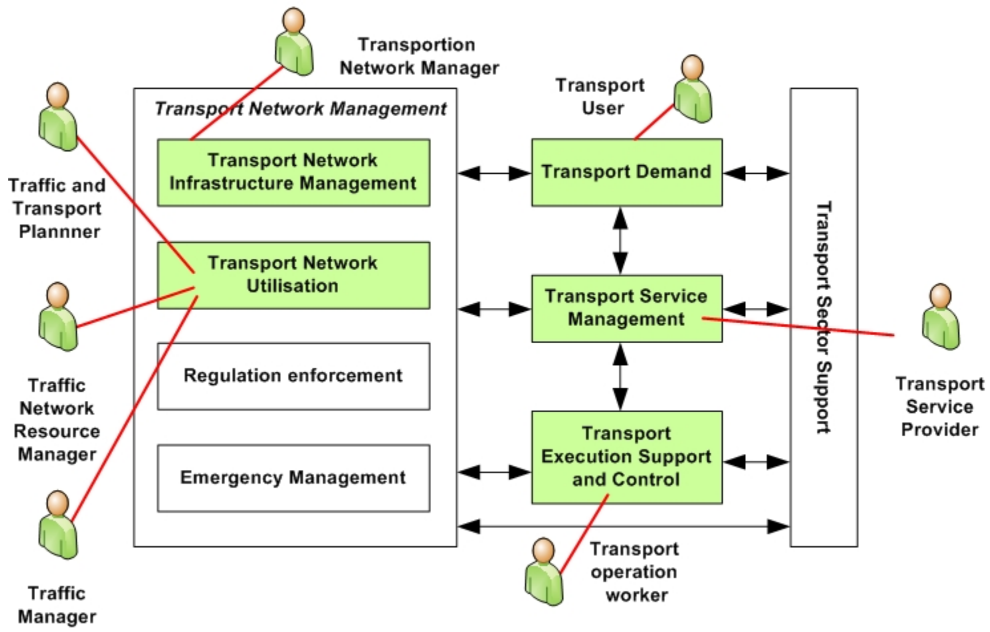

Figure 4: The relevant ARKTRANS roles

The ARKTRANS model has also been applied in EU research projects like SMARTFREIGHT (Natvig, M et al. 2009) and FREIGHTWISE (Fjørtoft, K et al. 2009).

The SC domain role model

The literature provided very few references on a role model for the SC domain similar to the one provided by ARKTRANS for the transport domain. Hence, it was found adequate to transform a process model to a role model (Foss, T 2009). The starting point for the transformation was the Supply Chain Operation Reference model as defined and maintained by the Supply Chain Council (SCC 2010). The SCOR model was chosen for the following reasons:

- The process model was technology independent
- The process model was internationally applied
- The process model was stable and continuously maintained and
- The process model was based on international or de facto standards

The SCOR process model focuses on five different operations or processes in the SC, see Figure 5:

Figure 5: The SCOR operation (process) model (Source: SCC 2010)

The process model was transformed to a role model focusing on the transport related sub-processes for each of the main processes. The resulting roles were called *Planner*, *Purchaser*, *Producer*, *Deliverer* and *Returner*. Although being abstract and somewhat different from the terms used in the SC domain, the names of the roles reflect as far as possible the associated main processes in the SCOR operation model. A more comprehensive description of the model transforming is given in Foss, T (2009).

A common role model

The reason for transforming the SCOR model was to enable a comparison of the transport domain role model and the SC domain role model to have one common model connecting the SC and transport domain. It was found by comparing the responsibilities of the transport domain roles with the transport related responsibilities of the SC roles that all SC roles could easily be mapped with the Transport domain role called *Transport User*. Hence, the common role model for the two domains became the fundament for the functional interoperability described in this paper.

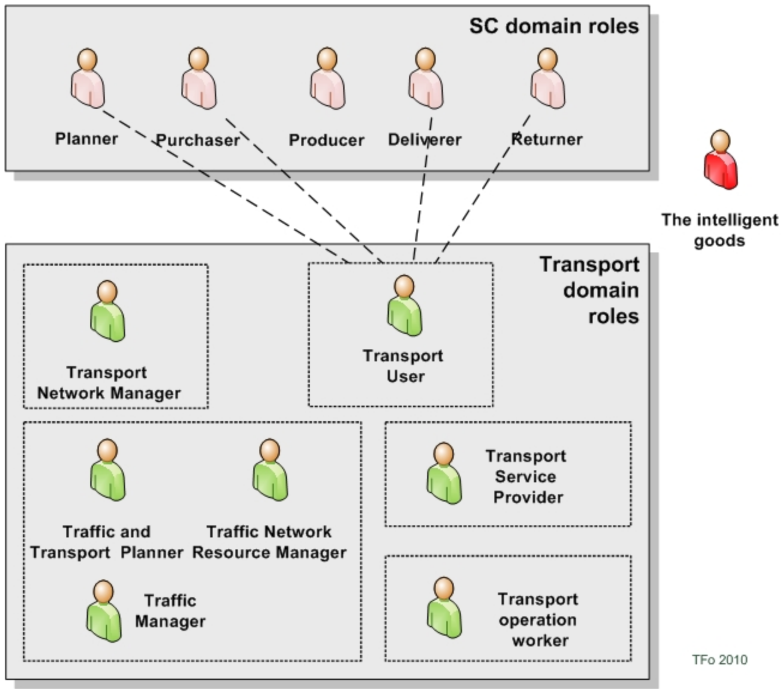

Figure 6: The common SC and transport domain role model (The INTRANS role model)

Figure 6 shows a proposed role that has not been described yet, i.e. *The Intelligent Goods*. The role is a common element for both domains and is a crucial part of the integration of the control models that are explained later. The main responsibilities of this role are to (Foss,T 2009):

- store and protect information linked to goods, e.g. content, transport route, time schedule, critical limits as temperature and gravity deceleration (shock resistance)
- monitor the transport of the goods in relation to planned and stored route information and other limitation attributes and store and/or send messages (alarms) when deviations are registered
- Communicate with the transport environment of the goods, e.g. roadside equipment for traffic management or gate equipment in terminals for following up by the *Transport User*, e.g. the *Deliverer* in the SC domain

The ARKTRANS framework would regard the goods as an object having the role of the *Transport User*, i.e. a role defining the transport demand by the information stored in the intelligent goods. However, in line with the INTRANS perception of the intelligent goods the intelligent goods is regarded a unique and individual role in this paper. The execution of the role is done by the equipment attached to the goods, i.e. the On-Goods Equipment (Foss, T 2008). Further research in this field is required.

The functional model enabling functional interoperability

The functional model for the SC and transport domain can be described by the responsibilities or the processes that are relevant for the two domains, e.g. by SCOR for the SC domain. It should be noted that this paper is only focusing on the control systems for the two domains concerning the functional interoperability. A control system is in this paper defined as a set of functions that supports the decision takings in the SC domain and the traffic monitoring and management in the transport domain. A core element in the control systems for the two domains is the On-Goods Equipment (OGE) which also has its own set of functions supporting both the set of functions in the SC domain and the set of functions in the transport domain. Hence, the integration of the control systems is enabled by means of the OGE which in this environment is defined as an individual system.

Figure 7 shows the proposed principle for the different systems and their interconnections in order to achieve functional interoperability. The OGE can be accessed via Access Points in the SC domain and the transport domain. In some cases the two types of Access Points can be the same physical and logical point.

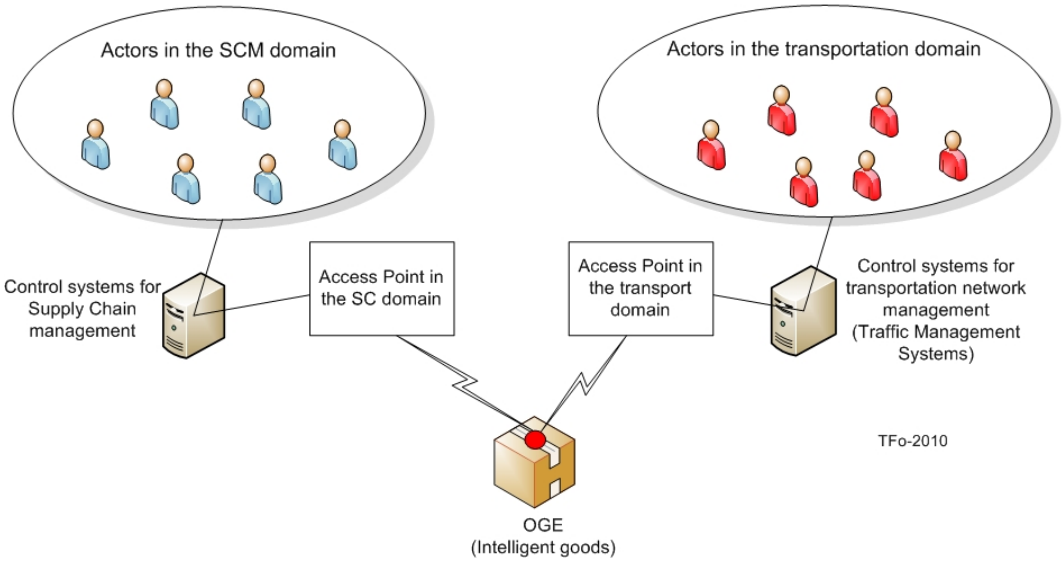

Figure 7: Principle for the interconnection between OGE, Access Point and Control systems

A typical Access Point in the SC domain would be a device installed at the gates of a warehouse communicating with all goods (transport items) that passes through the gate in and out of the warehouse. A typical Access Point in the transport domain could be a gantry or a pole (roadside equipment) with a similar device as described above communicating with the transport items passing the roadside equipment. The communication could go directly or via the On-Board Equipment (OBE) installed in the vehicle transporting the goods. An example of a common Access Point could be a device at the entrance of a terminal. The communication between the device and the OGE could be used by both the SC domain control systems and the Transport domain traffic management systems.

The functional interoperability requires a common set of functions on both sides of the interface. Regarding the intelligent goods as a system in itself the functional interoperability can be described by a class diagram which is a graphical presentation of the involved systems, their attributes and operations. Figure 8 shows a Class diagram (UML notation) of the Access Points, the Control systems in the two domains and the OGE. The common Access Point is for simplicity reasons not shown in the figure. Each box represents an object, e.g. an OGE or a Control system. The name of the object is written in the upper part of the box. The middle part of the box includes the proposed data elements. The OGE data element called uniqueTransportItemIdentity is mandatory in all OGE while the rest are optional. The lower part of the box includes the proposed functions in the OGEs and Access Points. Some proposed examples on the SC control and traffic management applications are given in the later chapter Findings and Conclusion.

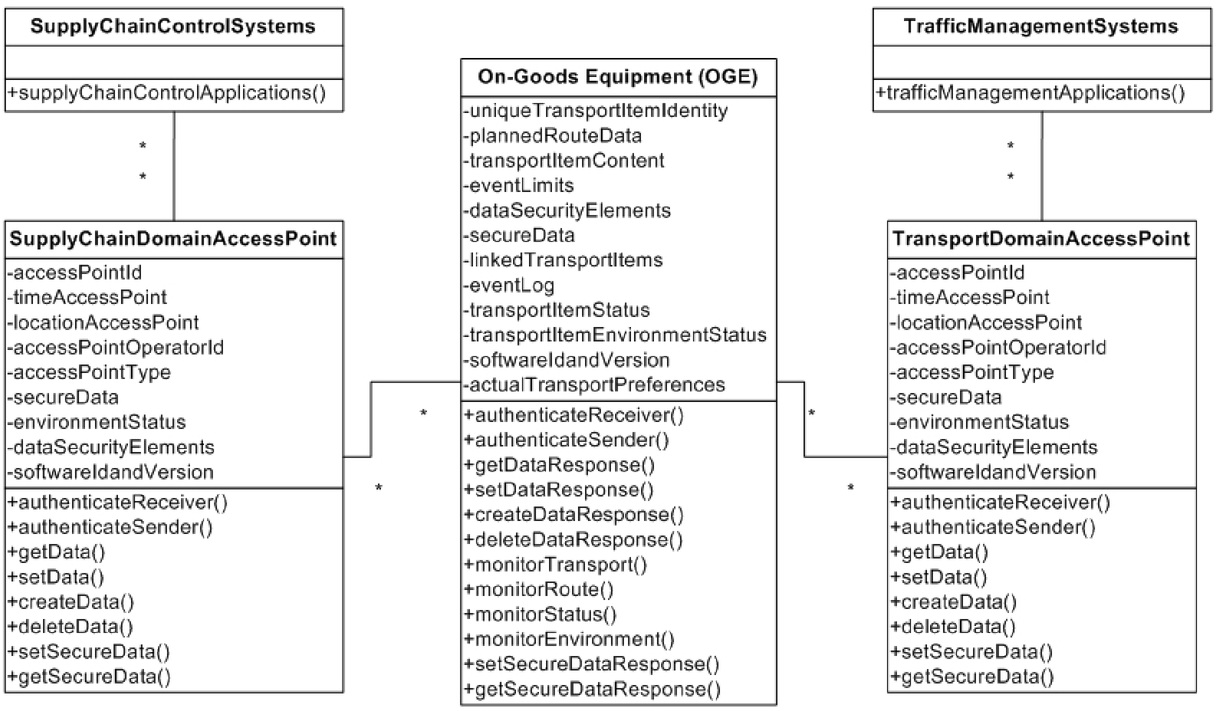

Figure 8: The Class diagram for the high level system point of view

The proposed functions for the Access Points represent a kind of middle ware between the intelligent goods and the control systems in the SC domain and the traffic management systems in the transport domain. The basic set of functions ensures functional interoperability and the control system and the traffic management systems can develop their sector specific applications for their own use, e.g. traffic monitoring in the transport domain and a track and trace application in the SC domain.

Table 1 shows the proposed set of basic functions (INTRANS middleware) given in the class diagram in Figure 8. It should be noted that the set of functions is not complete and should be subject to further research concerning the *Transport User* requirements both seen from the SC domain actor's point of view and the Transport domain actor's point of view.

Table 1

Basic Access Points and intelligent goods function	**Description**
authenticateReceiver	Enables the system to authenticate the receiver of the information before the information is sent using security mechanisms and security keys
authenticateReceiverResponse	Response to the authentication request
authenticateSender	Enables the system to authenticate the sender of information before or after the information is sent and before the information has been used
authenticateSenderResponse	Response to authentication request
createData	Enables a system to create data, files, archives etc in the system its communicating with
createDataResponse	Response to the create request
deleteData	Enables a system to delete data, files, archives etc in the system its communicating with
deleteDataResponse	Response to the delete request
getData	Enables a system to retrieve specific data stored in another system, e.g. specific attributes or records in an event log
getDataResponse	Response to the get data request
getSecuredata	Enables a system to retrieve secure data that requires security keys for the retrieval
getSecuredataResponse	Response to the retrieve secure data request
monitorEnvironment	Enables the intelligent goods to monitor its environment, e.g. temperature and humidity and send messages or store events in a log when limits are exceeded
monitorRoute	Enables the intelligent goods to monitor the route, e.g. by comparing actual time and place with planned time and place and send messages or store events in a log when deviations limits are exceeded
monitorStatus	Enables the intelligent goods to monitor its status, e.g. its internal temperature and humidity
monitorTransport	Enables the intelligent goods to register specific events and store them in a log or send messages when specific and pre-defined events are registered, e.g. shocks above pre-defined limits.
setData	Enables a system to write data to another system
setDataResponse	Response to the write request (confirmation of fulfilled command)
setSecureData	Enables a system to write security related data, e.g. security keys, to

Basic Access Points and intelligent goods function	Description
	another system
setSecureDataResponse	Response to the write security data request.

Further research in this field is required.

The information architecture

Table 2 shows the proposed set of data elements needed for the middleware basic functions. It should be noted that the set of data elements is not complete and should be subject to further research concerning the *Transport User* requirements both seen from the SC domain actor's point of view and the Transport domain actor's point of view.

Table 2

Data element	Description
accessPointId	Unique identification of the Access Point
accessPointOperator	Unique identification of the organisation operating the Access Point
accessPointType	Unique identification of the type of Access Point, e.g. Wi-Fi based roadside equipment mounted on a pole or gantry
actualTransportPreferences (ATP)	The transport preferences for a specific Transport Item
dataSecurityElement	Data elements used for security mechanisms, e.g. security keys
environmentStatus	Data describing the environmental attributes of the Access Point, e.g. temperature and humidity
eventLimits	Limits for specific attributes, e.g. for the temperature attribute the lowest and highest acceptable temperature
eventLog	A set of records defining events that have been registered for one or another reason
linkedTransportItems	References to other transport items that are linked to the transport item, e.g. references to boxes on a pallet or pallets in a container.
locationAccessPoint	Unique identification of the location of the Access Point
plannedRouteData	A definition of the planned route for the transport item, e.g. departure time and location and arrival time and location for all links and nodes in the planned route
secureData	Data that are protected by a security mechanisms, e.g. a password or security key
softwareIdandVersion	Unique identification of the software (middleware) used by the Access Point (Software Id and version)
timeAccessPoint	Current time in the Access Point in line with ISO 8601
transportItemContent	A unique identification of the content of the transport item
transportItemEnvironmentStatus	The status of the transport item external environment, e.g. temperature and humidity

Data element	Description
transportItemStatus	A definition of the transport item status. The status could include issues like delayed/not delayed, internal temperature and humidity, damaged/not damaged. The status report could collect its information both from the eventLog, the monitoring of route and internal sensors.
uniqueTransportItemIdentity	A unique identification of the transport item (goods)

Table 2 covers the set of data elements that could be used being a crucial part of the functional interoperability between the control systems in the SC and transport domain. The set of data elements does not indicate which data elements are mandatory and which are optional. This requires further studies and more detailed use cases to decide. Neither is the detailed coding described in this paper and is subject to further research to find the best suitable coding being acceptable for both the SC and transport domain concerning the different requirements and control systems applications. The coding of the data elements should comply with international or de facto standards (Foss, T 2008), like the Electronic Product Code (EPC) provided by the GS1 which is a leading global organisation dedicated to the design and implementation of global standards and solutions to improve the efficiency and visibility of supply and demand chains globally and across sectors. (GS1 2010). The GS1 system of standards is the most widely used supply chain standards system in the world. The EPC standards can be downloaded from EPC web side (EPC 2010). A paper presented by the FREIGHTWISE project (Pedersen, T and Westerheim, H 2009) defines the main information flows between the four roles used in the FREIGHTWISE project and introduces the term Transport Execution Plan (TEP) which is a very relevant set of data elements regarding the intelligent goods and the integration of the SC and Transport domain. The TEP is further defined in (ARKTRANS 2010).

TECHNICAL INTEROPERABILITY

In this paper Technical interoperability is defined as the ability of two or more systems to communicate with each other, i.e. the communication services and data transfer are common on both sides of the interface between the systems. In the integration of the control systems in the SC domain and the transport domain there are several crucial interfaces as shown in Figure 9. Interfaces to internal and external sensors are not included, e.g. temperature and humidity sensors and positioning sensors based on GPS or the future GALILEO satellite navigation system.

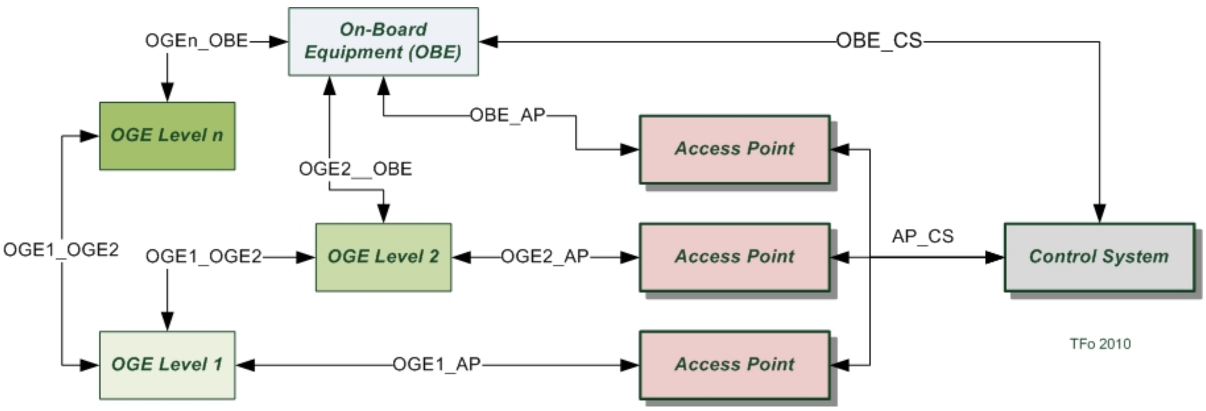

Figure 9: Crucial interfaces in the integration of SC and Transport domain control models

Table 3 describes the interfaces and gives some examples on possible solutions based on a feasibility study on possible technologies for intelligent goods (Cerasi, I 2009) and an inventory of wireless communication for ITS systems (Mahmod et al.). The OGE Level n is just there to indicate that there will be several levels of the OGE in the same way as RFID tags have been classified by EPC (EBC 2010). Further research in this field is required.

Table 3

Interface notation	**Description**
OGE1_AP	Air-interface between the OGE Level 1 and the Access Point. The Level 1 OGEs will be an OGE with limited data and communication, e.g. an RFID tag communicating on 13.56 MHz in compliance with ISO 14443 which has a typical read range up to 1 meter. An example on this interface could be an OGE (RFID tag) on a box on a conveyer belt in a warehouse where the conveyer belt is part of the warehouse internal transportation network and several Access Points (ISO 14443 compliant read/write equipment) were installed close to the conveyer belt.
OGE1_OGE2	Air-interface between OGE Level 1 and OGE Level 2. The OGE1_OGE2 interface should be the same as OGE1_AP. An example here could be the communication between an RFID tag on a box and the RFID tag fixed to the pallet where the box was loaded.
OGE2_AP	Air-interface between the OGE Level 2 and the Access Point. The OGE Level 2 will be an OGE that requires communication both with OGE Level 1, Access Points and On-Board Equipment. The communication range (5 – 10 meters) will require the OGE to have its own power supply (battery) and feasible frequency bands will be UHF and Microwave. An example here could be the communication between a tag on a pallet and an Access Point installed at the gate of warehouse or a tag on a container passing an Access Point, e.g. the entrance gate at a terminal.
OGE2_OBE	Air-interface between the OGE Level 2 and the OBE. The interface should preferably be the same as the OGE2-AP
OBE_AP	Air-interface between the OBE and the Access Point. The OBE will have its internal power supply (battery) or external (connected to the power supply of the vehicle in which the OBE is installed). The OBE will be fixed in the vehicle and will most probably provide other

Interface notation	**Description**
	applications than those used by the control systems described in this paper. This means that the OGE most probably will have installed one or more of the following communication types used for ITS applications (Mahmod et al): - Cellular network communication, e.g. GSM, GPRS and UMTS - Wireless LAN (IEEE 802.11) - Dedicated Short Range Communication (DSRC) - Infrared - Millimetre-wave - Continuous access for land mobiles (CALM) One could foresee that further research on this issue could lead to a classification of the interface in different sub-classes reflecting different SC and Transport domain applications and requirements.
OBE_CS	Air-interface between the OBE and the Control system. This interface could be a sub-set of the OBE_AP interface excluding communication types that do not support long range communication.
AP_CS	Wired (fixed) interface between the Access Points and the Control system(s). The interface definition could be based on a choice between several possible standardised communication protocols, e.g. TCP/IP.

In relation to the transport and SC domain applications it is also necessary to include an object called On-Board Equipment (OBE). The equipment is installed in the vehicle and is able to communicate with the vehicle environment, e.g. by Dedicated Short Range Communication (DSRC), GPRS, GSM, Wi-Fi or other protocols. It can store, protect, handle and communicate information related to the vehicle itself or its cargo. It is widely used for the Electronic fee Collection (EFC) application. It can also be used for applications like traffic information, route guidance (navigation), fleet management, traffic safety (warnings and even overtaking the manoeuvring of the vehicle) and other similar applications. The OBE will be an important link between the OGE and the Access Point regarding communication and accumulation of data stored in several OGEs. Figure 10 shows the proposed principle and hierarchy of OGE, OBE, Access Points and control systems. Further research in this field is required.

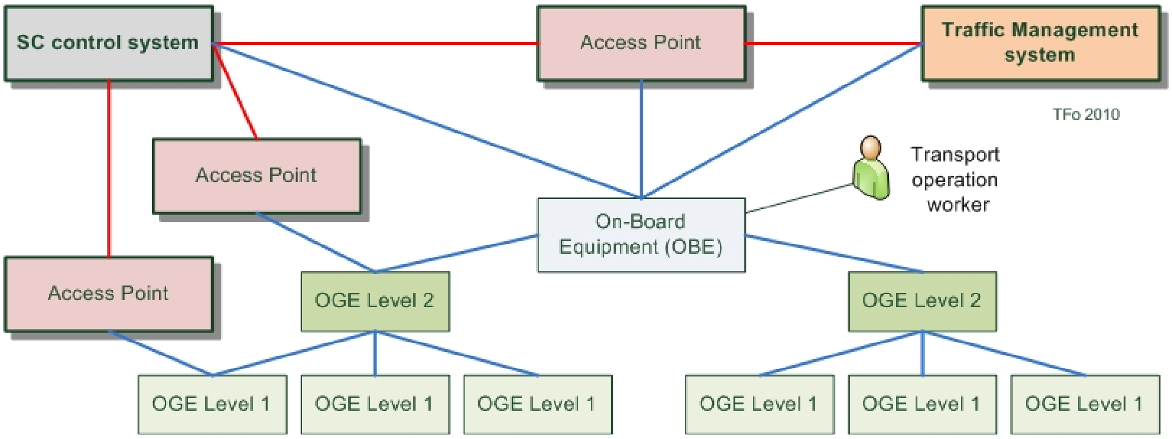

Figure 10: The hierarchy of OGE, OBE, Access Points and control systems

- The OGE on the level 1 can always communicate with an OGE on a higher lever and an Access Point. Level 1 represents the level with the less data storage and handling capacity as well as communication alternatives, e.g. a very simple Radio-Frequency Identification (RFID) tag.
- The OGE on the level 2 or higher can always communicate with OGEs on a higher or lower level, and Access Point and an OBE. It is foreseen several levels of OGEs depending on their data management, security, functionality and communication capabilities.
- The On-Board Equipment can communicate with OGEs on level 2 or higher, Access Points and directly with the traffic management and SC control systems. The OGE will in most cases be able to communicate with the driver of the vehicle via displays, keypads and sounds.
- The red lines are indicating wired connections while the blue lines are indicating air interfaces.

Figure 11 shows a simplified picture of the high-level information flows in relation to the integration of the control systems in the SC and transport domain. Further research is required.

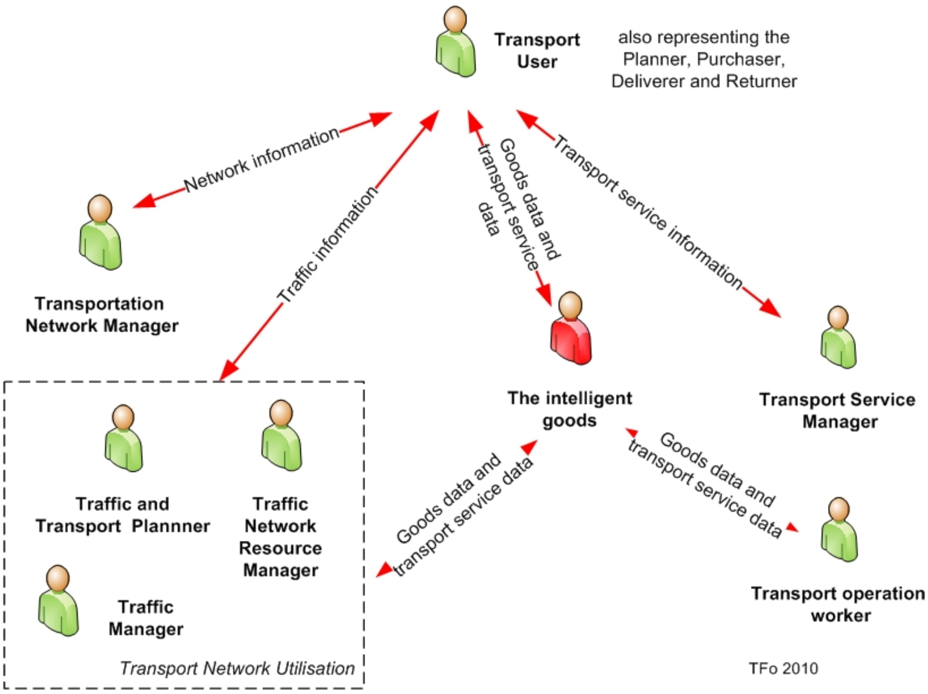

Figure 11: Simplified picture of crucial information flows

FINDINGS AND CONCLUSIONS

The Transport domain applications

The main objective of the roles in the transport domain as defined in the INTRANS project is to control the transportation networks, e.g. road networks, rail networks, air corridors and fairways (sea). The control or management of the transportation networks shall move persons and goods in the most efficient, safe, secure and environmental friendly way. Transfer Nodes, e.g. terminals, are also regarded as part of the transportation network. The applications for the management of the transportation infrastructure will benefit from easy and available access to information on which type of goods is present in the transportation network, where the goods is and at what time. A typical example is that it will be of major importance for the Traffic manager of a tunnel to know at any time what type of goods is in the tunnel and where in the tunnel the goods is. The same could be said for the operator of a terminal. It could be solved by manual methods in both occasions but the intelligent goods (the OGEs), the Access Points and the traffic management applications build upon the information exchanged at the Access Points would enable an automated, effective, safe and secure operation of the tunnel or the terminal. The following sub-chapters propose how the findings and results may be utilised in the transport domain.

Transportation Network Utilisation

Of the four sub-domains shown in Figure 3 this is the most relevant one concerning the integration of the control/management systems in the SC and transport domain. In ARKTRANS 2010 the Transportation Network Utilisation sub-domain has been defined by 4 use cases: Plan Transport Network Utilisation, Perform Operational Traffic Management, Manage Transportation Network Resources and Provide Transport means Supportive services (each of these use cases are further split to lower logical level use cases). The findings from the INTRANS research project for three of these use cases are described below.

Plan Transportation Network Utilisation
The planning of the transport network utilisation is the main responsibility of the role *Traffic and Transport Planner*. In ARKTRANS 2010 the use case Plan transport network Utilisation is divided further into 5 use cases on a lower functional and logical level: Perform transportation Planning and Optimising, Plan transport service availability, Perform Traffic Planning and Optimising, Plan Transport Demand Management and Plan Transport Means Supportive services. The planning and optimising of the utilisation of a given transport network requires statistical information about the transport infrastructure, the objects to be transported and the vehicles that will transport the objects, e.g. persons or goods. The detailed statistics on goods based on the information collected from Access Points is expected to improve the quality of the planning and optimising. Planning of the transport services availability may also benefit from the same statistics as above. In cases with limited capacity the statistics could for instance be used to give priority to certain types of goods.

Perform Operational Traffic Management
The operational traffic management is the main responsibility of the *Traffic Manager*. The use case is probably the one that will benefit most from a common infrastructure with the SC domain and the implementation of intelligent goods (the installation of OGEs on transport items). *It should be noted that by Transportation Network is also meant nodes and terminals*. The use case has been divided further in 5 use cases: Perform Operational Transport management Planning, Monitor Traffic situations, Perform traffic Control, Manage incident, and Manage Transportation Network Resources. Perform Operational transport Management Planning may use information from Access points to prepare short-term plans for traffic management, e.g. special types of goods are registered in a network and the special type of goods requires specific traffic management measures. The use case Monitor Traffic situations will benefit from the information that is collected at the Access Points. First of all it will give a detailed overview of the goods, e.g. hazardous goods, that is present in the network and a dense network of access points in urban areas enables a close follow-up and tracking of the goods through sensitive areas. Perform traffic control will also benefit from the possibilities of collecting accurate information about specific transport items moving around in the network including terminals. It will support the Traffic manager in assessing the traffic situations and decide on priorities and access rules for specific transport items and the transport means that transport the specific transport items. Specific routes can be assigned to transport means, e.g. a truck with hazardous goods may be given a certain set of transport

links and nodes to follow through a city. The individual management is possible via the Access points and the On-Board Equipment with an interface to the driver. The data collected at the Access points may also be used for a classification of the transport means and the classification may be used later in traffic management of individual vehicles. An import task of the *Traffic Manager* will be to detect and handle incidents. Any information about the cargo of the vehicle(s) involved in an incident may support the *Traffic Manager* in the handling of the incident, especially in those cases where the cargo contains hazardous goods. Further research in this field is required.

Manage Transportation Network Resources
The knowledge of the content of the cargo may support the *Traffic Manager* in taking decisions in relation to the use of transportation Network resources, e.g. transit areas, ramp areas and loading/unloading areas.

SC domain control systems applications

In the INTRANS project the SCOR operational process model was transformed to a role model enabling a comparison of the role model in SC domain with the role model in the transport domain. It was proved by a comparison of the transport related responsibilities that all the roles in the SC domain could be mapped to the role of the *Transport User* in the ARKTRANS role model in relation to the transport related services required by the different SC roles (Foss, T 2009). The *Transport User* role is related to the four use cases Administrate Transport, Prepare and Plan Transport, Manage Transport and Manage Transport Experience. These four use cases together with the use case Manage Public Purchase of Transport Services constitute the sub-domain Transport Demand, see Figure 3 and 4. In addition to the transport related services each of the main processes in the SCOR model may benefit from the introduction of intelligent goods (represented by the OGE), Access Points as defined in this paper and a common ICT infrastructure with the transport domain. Some of the major findings from the INTRANS research project are described below. The process Make, defined as processes that form product to a finished state to meet planned or actual demand (SCOR 2008), has less importance in relation to the integration of the SC and transport domain and is left out below. The following sub-chapters propose how the findings and results may be utilised in the SC domain.

Plan

The SCOR definition (SCOR 2008) of the Level 1 Process Plan is: Processes that balance aggregate demand and supply to develop a course of action which best meets sourcing, production and delivery requirements. Transportation will be one of the issues that have to be planned. Detailed statistics from Access Points may be used as input to the high level transportation plans for the Source, Deliver and Return processes.

Source

The process Source is defined as: Processes that procure goods and services to meet planned or actual demand. The SCOR model enables three different strategies for production: Make-to-Stock (inventory driven), Make-to-Order (Customer order driven) and Engineer-to-Order (Customer requirement driven). The consequence of this is that all the level 1 processes (except Return) has been detailed in three different sets of sub-processes. The second level process S1 Source Stocked Product has a third level process called Schedule product Deliveries. As this process is inventory driven the use of OGE's and Access Point is assumed to be beneficial for the execution of this process. Two level 3 processes that are common for all three sub-sets are the processes Receive Product (S1.2, S2.2 and S3.4) and Transfer product (S1.4, S2.4 and S3.6). It is quite evident that these processes will benefit from the implementation of OGE's and Access points.

Deliver

The process Deliver is defined as processes that provide finished goods and services to meet planned or actual demand, typically including order management, transportation management and distribution management (SCOR 2008). In (Foss,T 2009) it was found that the SCOR *Deliverer* role matched the *Transport User* in relation to transportation. The INTRANS findings related to the Deliver process is therefore described by the ARKTRANS framework. Table 4 shows the Main use cases defined in ARKTRANS and the similar SCOR process. The strategy chosen is Deliver Stocked product. Deliver Make-to-order and Deliver Engineer-to-Order have many of the same processes but deviates somewhat in the start of the set of processes. In some cases a SCOR process has been matched with two ARKTRANS use cases. The reason for this is that the process and use case is not exactly matching each other or that it requires a more detailed study to find the final matching (if existing), e.g. going to lower levels of SCOR processes. Further research in this field is required.

Table 4

ARKTRANS use case	**SCOR process**
Administrate Transport - Manage Contract - Manage Transport Booking - Manage Market Information - Manage Long Term Demand	 D1.1 Process Inquiry and Quote D1.2 Receive, Enter and Validate Order (D1.3 Reserve Inventory and Determine Delivery Date) (D1.4 Consolidate Orders) D1.15 Invoice
Prepare and plan transport - Gather Information - Define General Transport Preferences - Define Transport Demand - Find Transport Alternatives - Manage Transport Execution Plan (TEP)	 D1.3 Reserve Inventory and Determine Delivery Date D1.4 Consolidate Orders D1.5 Build Loads D1.6 Route Shipments D1.7 Select Carriers and Rate Shipments

ARKTRANS use case	SCOR process
- Manage Itinerary - Manage Tender Request - Request Transport Means Sharing	
	D1.8 Receive Product from Source or Make D1.9 Pick Product D1.10 Pack Product
Manage Transport - Activate Transport Product - Receive Context Related Information - Manage Transport Status - Monitor Transport Items - Track and Trace Transport - Manage Transport Information Exchange	 D1.11 Load Product and Generate Shipping Docs D1.12 Ship Product D1.13 Receive and Verify Product by Customer
	D1.14 Install Product
Manage Transport Experience	

There are at least three crucial use cases that are common for the SC domain and the transport domain: Manage Transport Status, Monitor Transport Items and Track and Trace Transport. Both domains will benefit from an integration of the control/management systems and the implementation of intelligent goods (represented by the OGEs). The network of Access Points will enable both the *Transport User* represented by the *Deliverer* or by the *Sender*, *Receiver*, Consignors, Consignees or Cargo Owners and the *Transport Service Provider* to monitor, track and trace the transport of the goods (transport item) and to handle a comprehensive set of transport information.

Return

The process Return is for Level 1 defined as processes associated with returning or receiving returned products for any reason. These processes extend into post-delivery customer support (SCOR 2008). The transport related processes on lower levels are more or less the same as those for Deliver. From a SC point of view some of the other processes in Return may benefit from the integrated infrastructure, e.g. for inventory purposes by automatically registering the transport item in and out of temporary stocks or start or end of transport chains.

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