The Potential Effects of Advanced Transportation Management on Transport Operations

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ABSTRACT

The purpose of this paper is to find functionalities provided by Advanced Transportation Management (ATM) systems that contribute to more effective transport operations. To prepare the paper, a literature study was conducted, looking for relevant up-to-date literature within the fields of transportation, logistics, ICT and environmental impacts caused by freight transportation. Based on the results from the literature review and previous work, the Smart Transportation Management model was recognized as useful framework for data collection. The data collection was carried out by interviewing representatives from companies and organizations that are considered experts in various aspects of advanced transportation management. The approach was to identify functionalities of different components of the conceptual Smart Transportation Management model; Smart Freight, Smart Vehicle and Smart Infrastructure, and see the potential benefits it will bring to transport operations. Many functions were found, including automatic identification, dynamic routing, dynamic traffic information, etc., that have potential impacts on transportation operations.

Keywords: Logistics, advanced transportation management, smart goods, smart vehicle, information technology.

INTRODUCTION

Advanced information technologies and information systems have been available for decades that aim at improving business operations for different industries. The number of implementations of software applications for the purpose of operational planning including warehouse operation, inventory planning, production planning, material requirement planning and similar has mounted in recent years and still are (Jonsson et al., 2007). The benefits of such software has been proven by showing more efficient operations, lower inventory levels, better customer service through better inventory availability, decreased fulfillment time, and increased delivery reliability (Vaugan, 2003; Ustundag, 2009).

The same cannot be said about information and communication technologies (ICT) and information systems (IS) aimed for the transportation industry including mobile solutions for truck operations. The availability of various solutions on the market is greater than ever but companies hesitate to invest in the applications and associated equipment. One of the reasons may be that managers do not fully believe that promised benefits will be realized and a reasonable return of investment achieved. This attitude is logical, not much evidence exists that show the benefits of the technologies and the systems within the carrier industry. Hence, spite the availability, most transportation companies in Europe and the USA operate without much ICT and IS support (Stefansson, 2007) for their operation of mobile units. At the best, technologies and systems have been implemented to track vehicles as customers´ requirements in many industries today demand tracking and tracing capabilities and even more advanced event management to secure delivery precision and reliability (Engström, 2005).

At the same time as the quest for increased operational efficiency has escalated due to increased competition and an urge for lower operational costs. In addition, new requirements have entered the industry that needs to be taken into consideration. These requirements are on environmental impacts and safety/security issues.

The environmental impacts and its relation with green house gases (GHG) is known and a growing global concern. The contemporary lifestyle of our societies is largely supported by multitude of transportation activities to supply demands of raw material and finished products to awaiting customers. The amount of GHG emissions caused by transportation operations globally is 14% of the total emissions (Stern, 2007). Compared to passenger transportation, freight transportation is rapidly increasing and does not show any tendency of decreasing. Also, freight transportation produce substantially more GHG of the total vehicle emissions compared to passenger transportation (Taniguchi, 2001). In the EU no less than 44% of the freight is transported by vehicles on roads, compared to 10% by rail, 4% by inland water and 42% by sea (EC 2006). Between 1990 and 2004 the transport sector increased its emissions by 28% (EC, 2006). At the same time the producing industry of Europe has decreased their emissions by 18%. Decreasing the emissions generated by transportation operations will be necessary to be able to reach long-term goals for reducing GHG both globally and in the EU. Requirements of estimating the impacts of transportation in form of carbon emissions have increased and it has become more common to find demand of estimation of products' carbon footprint (Stern, 2007), even if not fully realized in many industries.

Without any doubt, ICT can create many utilities, but it does not come free of charge. A particular case is the transport operators who are currently subjects of significant pressure to incorporate new ICTs into their operations from vehicle suppliers, government as well as their customers directly or via their contracted Logistics Service Providers (LSPs). Transport operators are often not able to employ or develop own technical competence, as they are generally very small companies. More than half of Swedish transport operators, for instance, are operators with single truck (Swedish road adm., 2006) - operating at a very small profit margins.

Although transport operators and logistics service providers are at the heart of the current development of distributed data capture, processing and communication in supply chains, most literature in the field of logistics and ICT takes the perspective of the transport buyers e.g., (Landers, 2000; Spekman, 2006), LSPs e.g., (Stefansson, 2006; Durr, 2003) or government e.g., (McKinnon, 2006; Tsai, 2006). Very few publications analyse impacts of ICT on different dimensions; operation and environmental impacts.

The purpose of this paper is to find functionalities provided by Advanced Transportation Management (ATM) systems that contribute to more effective transport operations and the posed question is *what functions can be found* that benefit the industry in one way or the other. To prepare the paper, a literature study was conducted, looking for relevant up-to-date literature within the fields of transportation, logistics, ICT and environmental impacts caused by freight transportation.

The outline of this paper is that the methodology applied for preparing this paper is explained first, then the results of the research on the different areas is described and finally implications and conclusions are expressed.

METHODOLOGY

The underlying approach used for the research behind this paper is based on literature studies as well as case studies. The relevant literature has been reviewed where the areas of transport operations and environmental impacts from transport operations together with informatics have been studied.

The empirical data was collected through interviews with experts within the transportation field as well ICT field related to transport operations. A system approach has been applied where not only was it important to understand the system components but also the relations between the components. To be able to do so, the components were studied in their natural relation to each other and not only in their causal relations (Arbnor, 1997).

Studying the smart freight included mainly secondary data as a lot of evidence can be found in the literature on automatic identification, RFID, decentralization of information, etc.

For the smart vehicle study, both truck manufacturer and suppliers of advanced transportation management were studied. The systems embedded in trucks today were considered and the providers of such system, including one of the major truck manufacturers in Sweden were included in the study. The vehicle information system providers were studied and the information systems they supply reviewed. This included a major Swedish provider of transport management and fleet management systems. Finally, the study of the smart infrastructure included experts in road administration as well as users of the infrastructure such as transport operators and logistics service providers.

The interviews that have been carried out were in all instances based on semi structured interview template, with experts in higher levels of operation. In addition, documentation was reviewed and when possible, direct observation done to accomplish a data triangulation (Yin 1994). The reason for choosing the semi-structured configuration was to increase the coherence between the interviews and make a within-case analysis easier (Eisenhardt 1989).

LITERATURE FRAMEWORK

The relevant literature from the field of transport operations, environmental impacts from transportation and information and communication technology (ICT) related to the transportation industry will be discussed in this chapter. The aim is to build up a framework to support the analysis of the benefits of Advanced Transportation Management (ATM) setups on these areas. The first are that will be introduced is the Smart Transportation Management concept (STM).

Smart Transportation Management

Smart Transportation Management setups can be defined in different ways. In most instances it is related to advanced ICT components that allow more sophisticated ways of planning, monitoring and controlling transportation management.

The Smart Transportation Management concept has been developed out of several scientific contributions that have been published in recent years. The main contributions are Smart Freight concept given by Lumsden and Stefansson (2007) where the main characteristic of the decentralized concept is described. The concept is based on the assumption that the freight carries data tags where considerable amount of data is stored. The participants in the supply chain have access to the relevant information by retrieving data from these tags and manipulate as needed. The introduction of this system has potential to reduce the actual mismatch between material and information flow. One of the advantages to move to a decentralized system is that many vertical transactions between a central system and the moving object will be avoided and this will contribute to the synchronization of material and information flow.

One of the major issues in the decentralized information and decision concept is that a local unit is supporting decision making and for that a unit with embedded logic needs to be provided. This has been called "enabler" in Lumsden and Stefansson publication (e.g. (Lumsden, 2007)). The role of the enabler is to collect data from RFID tags and interpret in a correct manner, store or send to the right database. This enabler can be situated in facilities such as warehouses or in mobile units such as trucks, forklifts, etc.

Lumsden and Stefansson (ibid) suggest the following capabilities of Smart Freight:

- process a unique identity
- is capable of communicating effectively with its environment
- can retain or store some data about itself
- deploys a language to display its features, production requirements, etc.
- is capable of support local decisions making

Another contribution is brought forward by Stefansson and Woxenius (2007) where a framework is developed for describing how activities carried out by transport operators (road haulers) and other partners in a supply chain can benefit from implementation of information and communication technologies. Figure 1 shows the benefits from ICT for various activities.

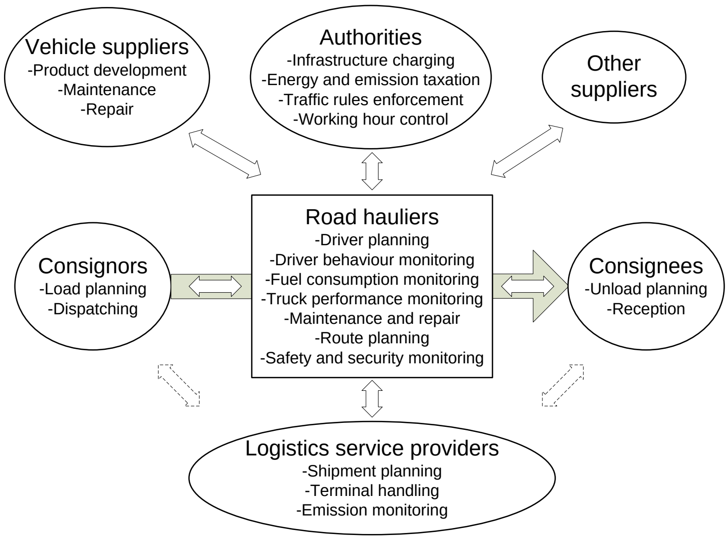

Figure 1 Activities benefiting from ICT support (Stefansson & Woxenius, 2007)

Stefansson and Woxenius (ibid) divide the benefits of advanced information and communication systems into three categories; managing vehicles and driver, managing the freight flow and customer contacts, and managing authority contact. The major characteristics of managing the vehicle and driver are: reducing fuel consumption and maintenance costs, better overview of driving hours, access information about road congestion or other relevant information about the traffic situation, reduce delays, etc. The major characteristics of freight flow and customer contacts are: reduce waiting time by providing customers with notification of impending delivery, reduce delivery and invoicing errors, reduce delivery mistake, improved customer service through "real time" visibility of arrival and departure and identification of problems en route. The major characteristics of managing authority contacts are reduced paperwork and administration costs, improved driving hour reporting and improved charging feasibility and common platform for charging policy.

Still another major contribution is the Smart Logistics Setup (SLS) proposed by Stefansson and Sternberg (2007). For the design of the SLS framework, a scenario of transportation and logistics setup was developed out of identified user requirements. The framework includes a high-end system solution that includes different state-of-the-art components such as an identification system based on Radio Frequency Identification (RFID) technology, an on-board vehicles information system that enables data and information execution, an embedded computer system that is integrated with many of the vehicle functions, and a communication system based on several of the existing telecommunication solutions to secure data exchange and distributed decision-making.

The final major contribution is put forward in an article by Stefansson and Lumsden (2009), Performance Issues of Smart Transportation Management. The essentials of STM systems are identified in that paper as Smart Freight, Smart Vehicle and Smart Infrastructure. Overview of these three essentials is described below.

Smart Freight

Smart freight, smart goods, and intelligent goods are used interchangeably in the literature and are partly synonyms. According to Holmqvist and Stefansson (2007) "Smart Goods" is characterized by a higher level of sophistication than traditional goods identification". This means that instead of using former technologies such as barcodes (to identify an item), it is now possible to furnish the freight, either individual items or the load unit, with new smart technologies, simply by using a modified RFID tag as a carrier of data. Holmqvist & Stefansson (ibid) further introduces and explain several technologies that are combined with each other, among others; RFID, GSM/GRPS and Web Technology (Kärkkäinen, 2003; Ghribi, 2000). When these technologies are combined together and the benefits from each are used, potential to reach maximum performance along with higher data exchange is possible.

Smart freight by itself has many components and relies on many technologies to enable operation. The use of RFID in the supply chain has the potential to provide real benefits in inventory management, asset visibility, and interoperability in an end-to-end integrated environment (Vaughan, 2003; Ustundag, 2009; Prater et al., 2005; Twist, 2005; Jones et al., 2005). By using RFID and other identification technologies supply chain visibility can be obtained (Lapide, 2004).

Smart Vehicle

A major issue in the STM system framework is the so-called Smart Vehicle. For this work, mainly distribution vehicles or trucks are in focus where the truck cabin is equipped with a vehicle computer system and identification of goods is done as freight is loaded or unloaded off the vehicle. Communication of this information to central systems is not necessarily carried out, in many cases the information is only stored in the vehicle computer system and in other instances, the information is communicated to a central information system, especially if deviations occurs or a pre-notification of arrival is needed.

Considering that information about the freight is captured while loading the vehicle and that the manifest is downloaded to the in vehicle computer gives the following:

- the possibility to minimize the risk of loading/unloading the wrong freight
- helps to load/unload in the right sequence
- makes it more visible to know how many assets which are used in the system
- proof of Delivery and Proof of Acceptance can be sent to the host system in real time

With such a solution, a link is established between the vehicle and the goods, something that is not seen in many operational systems today although exception occurs.

Smart Infrastructure

To complete the Smart setup in STM systems, the Smart infrastructure needs to be introduced. Smart Infrastructure can be divided into two parts; *digital* and *physical*. It is important to distinguish between these two, as they are so different in characteristics.

Physical infrastructure is not only the roads and bridges vehicles travel on. It consists of:

- roads
- tunnels
- ferries
- ports
- warehouses
- terminals and similar asset based facilities.

Towards this physical mart infrastructure, Smart Vehicles can have double directed information through the ICT systems that are part of the digital infrastructure.

The smart digital infrastructure retrieves, manipulates, stores and communicates data and information from the physical infrastructure to and from the Smart vehicles using different digital technologies such as sensors, cameras, databases, and positioning technologies. The Smart infrastructure enables information exchange about the goods, vehicles and infrastructure to be transmitted between participants as needed (Jones et al., 2005; Alvergren et al., 2007).

There is no common standard or definition of how a smart infrastructure should be designed or built. However, there have been efforts to describe how a possible smart infrastructure could be designed. Spieß et al. (2007) have focused on identifying and explaining the technical requirements of a holistic "Smart items infrastructure" (SII). With a service oriented architecture (SOA) they suggest a more flexible and adaptable infrastructure for ubiquitous computing. This SII cannot only fulfill current and future demands on Auto-ID, but also scale provide a foundation for the next generation smart items. This includes items with locally embedded units with processing power.

Decentralization is a very important part of the entire Smart infrastructure concept, and this also applies to the Smart items infrastructure. Some of the benefits according to include scalability, improved data accuracy and response times (ibid). Through the decentralization and implementation of more units with processing power the reliance on centralized databases and backend systems decreases, and overall system performance is assumed to increase and become more reliable. Some of its strength lies in being able to utilize currently used technology such as RFID while being open to and providing architecture that support the next generation of technology at the same time using open system architectures.

Yet another proposed decentralized Smart infrastructure architecture is the vehicle-to-vehicle-to-infrastructure (V2V2I) hybrid architecture (Miller, 2008). Miller (ibid) proposed two architectures, vehicle-to-vehicle (V2V) and a vehicle-to-infrastructures (V2I), and in this combines the two in order to reap the benefits of both. When investigating the viability of V2V and V2I Miller discovered some flaws in the architectures. One of the main concerns was how to handle the massive amount of data that was transmitted and processed and optimizing this was a very complex and hard issue to overcome. In order to address the main issues identified he combined the two architectures and created a hybrid architecture that enabled a limited number of vehicles to become gateways or hubs for the other vehicles in a specific area. This limited the requirements on bandwidth and processing capacity and provided a compromise in design that would give most of the benefits without the majority of the drawbacks.

FUNCTIONS AND IMPLICATIONS

To structure the functionality analysis the fundamental components Smart Goods, Smart Vehicle and Smart Infrastructure have been poised against the area of transport operation in this work. The structure was then used when looking for evidence of impacts from the literature as well as during the interviews with the experts.

Evidence from the literature was mainly found concerning transport operations and economics related to the three components of the STM setup. Much is found on identification technology and the benefits of quicker and more reliable identification that relates to Smart Goods. By automating time-consuming activities and removing the human factor, previously involved costs are reduced and errors are less likely to occur. In a supply chain perspective this leads to transparency and visibility throughout the chain and production (Lee & Özer, 2007; Boushka et al, 2002). With the use of RFID tags with sensors perishable or temperature sensitive freight can be monitored during the transport. Abusive and/or fluctuating temperature accelerates rapid growth of pathogens and specific spoilage organisms (Jol et al. 2005; Raab et al. 2008), causing safety problems and economic losses.

Advanced identification also allows transportation companies to monitor and adjust their operations to ensure that the goods is not damaged or spoiled in transit and further reduce claims for replacements. In relation to Smart vehicle, evidence of the need for track and trace applications are reported and the functions analyzed. The Smart freight is therefore preferably equipped with an automatic identification mechanism (such as RFID tag) that allows considerable amount of data to be stored and retrieved. In addition, read/write technology has to be in place and collected data needs to be submitted to a backbone system that is interoperable with the operators´ ERP systems. In addition, an enabler with embedded logic needs to be used to interpret the data and thereby support local decisions.

Much less is found in the literature on environmental impacts related to the different components of STM - more is found on general issues to decrease the impacts such as on fossil CO_2 emissions including Eco driving, technology developments and similar.

The literature study was followed with interviews with specialist with the area of transportation operation. The method being adapted from a Delphi study approach involved in-dept interviews where the specialists were asked to identify functionality that is possible to improve transportation operation in any aspect. The responders turned out to have hard time keeping their mindset to functionality and not to talk about technology or effects. To make the focus more clear, a simple explanative model was introduced where the relations was introduced as shown in Figure 2 below.

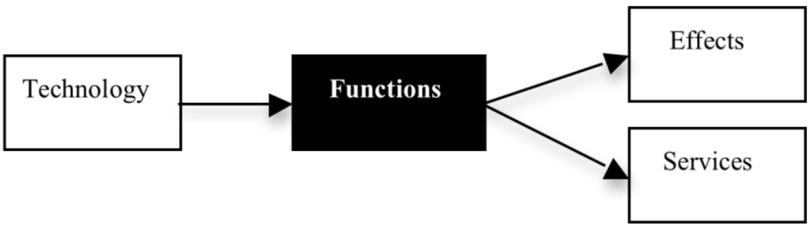

Figure 2 Functions are in focus during the interviews

A function that was mentioned by all respondents is a “Location” function. That function was considered to be very useful for many reasons. Some mentioned are to enable tracking of vehicles and thereby goods during logistics operations. Furthermore, the possible effects of having access to “Location” information would be to use it for road charging purposes and thereby having potential effects on the environment. For this function, technology was discussed but for the purpose of this research it was clearly stated that the technology is not relevant – the function of being able to locate a vehicle was in focus.

Related to the “Location” function was the “Carbon footprint” function mentioned. The possibility to track goods movements and then declare the carbon footprint was considered to be a future requirement and the location information together with effective tracking systems to enable vehicle – goods relations necessary for future environmental considerations.

Another function that was frequently mentioned was the “Routing” function. Having possibility to make more dynamic routing is considered positive and a clear overlap came across between traffic information and routing capabilities, as the function of “Routing” should take into consideration the traffic situation and even road situation. Together with this function, even a discussion of forecasting was mentioned so that routing could be done based on predicted traffic situation.

Still another function related to the previous “Routing” function was mentioned and that was goods related routing meaning that depending on the goods being moved, the routing mechanism would choose the most appropriated road or even based on limitations found such as forbidden dangerous goods movements in tunnels, etc.

A clear overlap between Smart vehicle and Smart infrastructure was experienced. Example is the “Routing” function, is it a part of the Smart vehicle only or does it include the Smart infrastructure. A common understanding is that it is part of the Smart vehicle as the hardware and software is part of the Smart vehicle capabilities but a dynamic routing cannot be done without an interaction towards the Smart infrastructure giving data on road and traffic situations, enforced limitations such as weight limitations, road work, etc.

When discussing environmental impacts, “Routing” came again up as a function and furthermore a connection to forecasts of road situations in front of the vehicle in some hours. This function would make it possible to slow down the truck to prevent finding it in a congestion situation as it would anyway be delayed was mentioned as an alternative and a function that would safe fuel.

Summary of the first round of interviews are found in Table 1 below.

Table 1 Summary of the identified ATM functionality

Smart freight	**Smart Vehicle**	**Smart Infrastructure**
- Autmatic Identification - Logic for handling	- Goods identification - Real time communication - Routing - Speed scheduling - Rest planning & Parking assistance - Security options - Theft prevention - Carbon footprint registration	- Location information - Road situation - Traffic situation - Dynamic routing - Saefty management - Security management - Infrastructure charging - Carbon footprint registration - Two way communication

The table shows the identified functions possible when Smart infrastructure is available and the necessary functions that are needed with the Smart freight and Smart vehicle areas to fully enable Smart infrastructure functionality. Many more functions are found within the Smart freight and Smart vehicle areas, but they are not in focus for this research.

CONCLUSIONS

The purpose of this paper was to find functionalities provided by Advanced Transportation Management (ATM) systems that contribute to more effective transport operations, not only in terms of economics, but also environmental impacts. The work included a literature study looking for relevant up to date literature within the fields of transportation, logistics, ICT and environmental impacts caused by freight transportation as well as in-dept interviews with experts within the field of transportation. The interviews revealed some major functionalities that are considered to be very valuable for many areas of transport operations. These areas include economical issues, safety and security issues, environmental issues and more. More specifically, the functionalities included automatic identification, dynamic routing, road charging, and more.

Practical implications of this work include possibilities of identifying what functionalities can be gained from ATM systems and thereby the potential effects of possible investments made in advanced technology related to transportation operation.

The functionality provided by Advanced Transportation Management setups have been introduced in this paper. Further research within the area is needed and new studies including more interviews with new respondents is required for further insights into the functions and moreover the effects these functions result in for the transportation industry. Furthermore, the effects are seldom only beneficiary for one single stakeholder, i.e. decreased fuel consumption is not only benefit transport operators, but also society as it reduces environmental impacts. Further research will therefore also need to include wider range of stakeholders in the supply chain to give better coverage of different perspectives.

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