World Journal of Science, Technology & Sustainable Development, Vol. 7, No. 3, 2010

INTELLIGENT CARGO – ENABLING FUTURE'S SUSTAINABLE AND ACCOUNTABLE TRANSPORTATION SYSTEM

Henrik Sternberg*[1], Chalmers University of Technology, Sweden
Andreas Hagen[1], Chalmers University of Technology, Sweden
Paolo Paganelli[2], Insiel S.p.A, Cesare Battisti, Italy
Kent Lumsden[1], Chalmers University of Technology, Sweden

Abstract: Today, the transport industry is facing increasing demands on reducing both the environmental impact and cost of freight transports. Another demand, coming from the end consumers, is the demand for ecological accountability, so-called ecological foot-printing, meaning that the emission of every freight movement is distributed to the freight. Previous research shows that transport planning, system integration and control are some of the key factors to achieve more sustainable transport setups. One of the major obstacles preventing these factors is the complexity of international supply chains, with several involved actors. Smart Freight is a holistic concept, integrating transport management and state-of-the-art technologies for freight tracking and vehicle monitoring, in order to enable improved management and accountability of freight transportation. The purpose of this research is to explore how Smart Freight can be used to control, track and reduce the environmental impact of goods transportation. This research is based on two in-depth case studies and a demonstration prototype of one of the studied transport setups. An extensive amount of data was collected between 2006 and 2008 through interviews, video filming, document studies, physical travel with the freight flows, seminars, prototype building, literature and desktop studies. The result of this research highlights the weaknesses in today's control of transport operations and presents a model for how Smart Freight enables a more environmentally friendly and accountable transport system.

Keywords: *transportation, intermodal, information sharing, information systems, environment, smart freight.*

INTRODUCTION

Environmentally effective logistics systems are crucial to environmental sustainability (Litman and Burwell, 2006). Freight transport's direct impact on the ecosystem is testified by its large carbon footprint, amounting for over 14% of global green house gases (GHG) emissions (Stern, 2007). Despite policy support and industry investments in favour of modal shift and inter-modal freight transport, the unabated growth of road transport continues. While attempts to direct cargo toward environmentally

[1]* Chalmers University of Technology, Div. of Logistics and Transportation, 412 96, Göteborg, Sweden, Email: Henrik.Sternberg@chalmers.se
[2] Insiel S.p.A, Cesare Battisti, 25-27, 401 23, Bologna, Italy

friendly transport modes are failing to meet expectations, logistics firms face problems of rising fuel prices, infrastructure saturation and the fierce competition typical of a commoditized sector (Brehmer, 1999, U.S. Department of Transportation, 2009). Demand factors, such as a reduction in heavy bulk transport, decentralized distribution and just-in-time services are actually sustaining the high growth rates of road freight traffic (Lumsden, 2006). Logistic operations have room for significant efficiency gains (Bowersox et al., 2000, Kalantari and Sternberg, 2009). Empty haulage rates (percentage of truck-km run empty) are reported by EU countries as ranging between 40% and 60%; that is, every truck would be running empty 50% of its working time. This indicator alone testifies to a wide efficiency gap to be filled, but logistics practitioners can easily point out several other inefficiencies, from useless trips due to poor planning or missing information links, to unwanted stops for lack of synchronization between transport modes or lengthy administration processes (Sternberg, 2008). At the same time, public authorities and private consumers request ecological accountability (Wackernagela and Reesb, 1997, Bartelmus, 2009) and global, continental, national and local legislation is taking hold (Rodrigue et al., 2001). Ecological accountability can be implemented through so-called ecological foot-printing, meaning that the emission (e.g., CO_2 emissions) of every freight movement is distributed to the retailed goods. Altogether, this creates new challenges for all industry segments (Halme et al., 2005).

This situation calls for new logistics models that can combine environmental sustainability, financial sustainability and ecological accountability. Environmental sustainability aims at finding solutions to reduce emissions and make freight transport more energy-efficient, e.g., IT support for the modal shift from road to rail and environment-aware route optimization solutions. Financial sustainability aims at solutions to save costs and protect market shares of individual logistic firms, e.g., improved planning and execution systems, and e-business tools simplifying management of multi-modal door-to-door shipments. Finally, the logistics system needs to take ecological accountability into consideration, through keeping track of the emissions caused by each activity in the production and transport of goods all the way to the end consumer. A holistic approach, including both the use of IT and business process re-engineering to tackle these challenges is necessary (Bowersox et al., 2000, Holmqvist and Stefansson, 2007). A holistic concept integrating technologies and decentralized freight information are Smart Freight, introduced by Lumsden and Stefansson (2007) and Intelligent Cargo (Eurodice, 2009, Schumacher et al., 2009). Other identical concepts to Smart Freight and Intelligent Cargo are Intelligent Freight, Smart Goods, etc.

The purpose of this research is the following: *To explore how Intelligent Cargo can be used to control, track and reduce the environmental impact of goods transportation*. This conceptual work is based on two in-depth case studies focusing on transport operators' information requirements and feasibility tests with a demonstration of prototypes based on both studies.

LITERATURE FRAMEWORK

The goal of this section is to establish a common terminology for the paper and explain terms and definitions that are used throughout the analysis. This chapter gives an introduction to logistics management, green logistics and smart logistics systems.

Logistics and transport management

Despite the potential energy savings that could be enabled through actively managing transport networks, transportation generally relies on fixed schedules and procedures (Kalantari and Sternberg, 2009). Traditionally, performance measurements associated with purchased transportation focus on two elements, namely purchase cost and carrier delivery performance (Ross, 1996), despite the fact that the total purchase cost is linear to the fill rate (actual utilization compared to maximum load capacity of vehicle) of the transports. Transport planning needs information on the two dimensions of flexibility, time and volume, to work effectively (Ross, 1996). Transport planning, enables *control*. Control is defined by van Aken (1978) as: *"Control is the use of interventions by a controller to promote preferred behaviour of a system-being-controlled."* Control of transport operations has three aims: efficiency (productivity), effectiveness and flexibility (Brehmer, 1999). Effectiveness, as efficiency, is usually used in a comparative, rather than in an absolute way (Brehmer, 1999). In this paper, focus lies on the transport aspects related to control of effective goods flows, where effectiveness is compared between the actual and potential way transport operations are controlled from a sustainability perspective. Effective transport operations is focused on executing transport operations in an energy effective way (meeting and responding to customer requirements) and avoiding unnecessary transport work caused by information and coordination deficiencies.

Green logistics

Green logistics is a general term that encompasses efforts to reduce the environmental impact from logistics operations, e.g., to reduce emissions (Björklund, 2003). Another term used is "Environmentally responsible logistics systems" (Wu, 1994). Often, the focus of Green logistics is on achieving intangible benefits such as image and reputation enhancement (Rodrigue et al., 2001), yet several studies have shown that reducing environmental impact, generally is cost-saving and financially sustainable for companies (Sternberg, 2007, Wu, 1994) This paper focuses on the transport part of Green logistics.

Lorry transports have the largest share in the pollution from transports. According to Opportunities for Rationalizing Road Freight Transport (McKinnon, 1995), "the amount of lorry traffic is influenced much more by changes in the organization of production and distribution than by variations in the physical mass of goods in the economy." These organizational changes are the results of decisions made at four levels:

1: Physical structure of the logistical system: determined by high-level strategic decisions affecting the number, locations and capacity of factories and warehouses.

2: Pattern of sourcing and distribution: determined by a firm's trading relationships with suppliers, sub-contractors, distributors and customers.

3: Scheduling of freight flows: the trading relationships are physically manifested as freight flows. The scheduling of orders determines how these flows materialize as discrete freight movements.

4: Management of transport resources: within the framework defined by decisions made at the previous three levels, transport managers can still exercise a reasonable amount of influence on road traffic levels through their choice of transport modes, carriers and vehicles, the planning of loads and routing of deliveries. In this paper levels 1 and 2 are out of scope and focus will be put on the two latter levels outlined by McKinnon.

Smart Logistics System

Stefansson et al. (2007) has suggested the following framework components for SLS (Smart Logistics System):

Collaborative logistics arrangement between the partners is a starting point for the transportation setup (Stefansson, 2006). Contracts have to be made which identify the mutual processes that are carried out, the technology for data exchange must be agreed upon and the data content or messages must be commonly determined (Power, 2005). Business models, trust and information sharing must be addressed.

Information sharing between partners, extended to not only allowing data and information to be exchanged by a common data server or message exchange but to include more data and information in RFID tags that follow the goods throughout the journey (Holmqvist and Stefansson, 2007).

Technology for supporting information sharing needs to take into consideration interoperability and each participant's capabilities in operating the specific technology (Power, 2005). Goods need data storage that can be read and written throughout the transportation setup without any difficulty and that data contents are agreed upon.

Decentralized information setup does facilitate local decision-making as more information needs to follow the goods (Schumacher et al., 2009). A decentralized information setup can enable a more effective mode shift in, e.g., ports and enable freight that can be handled by any reader-equipped terminal, departing from today's static transport networks.

Intelligent Cargo is the key for storing data and information at the goods level, allowing data and information to follow the goods on their way to their final destination (Holmqvist and Stefansson, 2007, Lumsden and Stefansson, 2007).

METHODOLOGY

The approach for this research is twofold: firstly, to support the analysis of the primary data, relevant literature on logistics, green logistics and information science has been reviewed; and secondly, empirical data has been collected from a dual case study.

The two case studies have been carried out through open observations and interviews, both structured and semi-structured within each case. In total, 70 interviewees were chosen from both operations and management, 43 in case study 1 and 27 in case study 2, to achieve a full picture of the studied transport setups. This led to a lot of duplicate information and several interviews did not present any new insight but increased the accuracy and reliability of the findings. All the questions from the structured interviews as well as the notes from the semi-structured interviews have been saved. Copies of all documents circulating in the flow were obtained. The two case studies underlying this research were carried out within two national Swedish research projects. In Case Study I, the first author observed the flow by physically travelling with the ferry and the carriers, and making several visits to the terminals, supplier, customer, administration offices and port facilities over a period of 9 months. Some of the interviews and observations on the Swedish side of the flow were carried out with the help of three graduate students. The researcher always supervised their work. The notes collected from the interviewees were compared and followed up for validity and reliability. The complete findings of the case study were published in a requirements report and were validated by both the responsible LSP (Logistics Service Provider) as well as one carrier. The findings were also validated against the findings of another information mapping study carried out by (Nyquist, 2007). Some results from the same project were published in Sternberg (2008)

Case Study II (part of the project "ITS-Support for combined transports") used an identical methodology. The first author was assisted by one PhD for the studies in Stockholm and by the second author for the studies in Skåne. Case Study II is previously unpublished.

Due to the novelty of the subject of the article as well as the conceptual nature of the paper, several delimitations apply. The studies of logistics sustainability have been focused on the transport area, neglecting other highly relevant factors, e.g., packing material and reverse logistics. Advanced network theories, e.g., balancing freight demand against capacity networks have not been dealt with. The sociological perspective on sustainability is not discussed in-depth and models of financial sustainability are just briefly mentioned. Cost/Benefit analysis or other types of cost reasoning have not been mentioned, nor has the enabling technological architecture been outlined.

EMPIRICAL STUDIES

This section outlines the dual case study underlying this research. Both cases deal with complete end-to-end transport setups, including a multitude of actors. None of the actors studied occur in both cases.

The transport setup chosen as case study I involve 12 main actors, but more are involved as the specific trailer operator can vary from time to time adding actors in several steps of the chain. The physical flow starts from a supplier in Hindås, Sweden and goes round-trip to Gent, Belgium. A LSP is responsible for end-to-end flow. The goods transported are components for the automotive industry.

Case Study II studies the distribution of electronics material for construction sites. A LSP is responsible for distribution from the supplier's central warehouse (located in western region of Sweden) to other LSP terminals or to end customers, depending on region. The distribution to two regions, Stockholm and eastern region of Skåne were studied. The shipments in Case Study II are to a large extent heterogeneous (Arnäs, 2007), e.g. copper cable (delivered on a drum, and the drum is normally returned to the supplier to be re-used), cable tunnel (delivered on a disposable drum which is recycled), various regular sized, palletized electronics components (some of them sensitive to pressure) and poles (5-10 meters), irregular sized.

Empirical summary

The introduction and literature analysis of this paper outlined effective planning, information use, collaboration, incentive models and enabling technology as necessary steps to achieve environmentally and financially sustainable logistics systems.

A simple model based on four questions (Q1 to Q4) was derived from the literature, with the aim of extracting the information needed to elaborate on how Intelligent Cargo can enable environmentally friendly and accountable transportation systems in the studied cases.

Table 1 Results of the empirical studies

Case Question	*Case I*	*Case II*
Q1	Fill rate is relatively high (60-70%), excluding the frequent ambulant transports dedicated to delayed shipments, or shipments detected late.	Relatively low fill-rate, due to bulkiness.
Q2	The responsible LSP, the ports, the Belgian warehouse operator and the ferry operator were paid according to volumes handled. The carriers were paid according to charter principle	The carriers were mainly paid with a certain percentage of the LSP revenue for a shipment. The large LSP was paid based on fixed slots on haulage lines.
Q3	The responsible LSP mainly planned transports according to a strict schedule, with fixed delivery and pick-up times, which also mean that they influenced the fill-rate of the other actors in the case. The ferry operator had to some extent the ability to influence fill-rate through load planning.	The responsible LSP made contracts with the carriers and the carriers were generally not allowed to carry freight for other companies except the LSP.
Q4	No active monitoring was carried out. Control triggered only as reaction on customer inquires or unforeseen events and delays in the setup.	Monitoring only made by the responsible LSP to ensure shipments arrived to the proprietary terminal.

Q1: *Generally, how well are the transports filled?* This question is based both on the staff interviewed and the observations of the researchers. Due to the bulk weight shipments the fill rate statistics of the operators was ignored.

Q2: *How were actors paid for the goods?* Looking at this factor was interesting in order to relate transport effectiveness to financial incentives.

Q3: *How is transport planning generally carried out and what actors can influence fill rate?* These questions look at the procedures involved in planning and transport.

Q4: *What active measures are carried out to control freight flows?* The aim of this question is to answer to what degree the freight operations are dynamic.

ANALYSIS

This section consists of two parts. The first part deals with the analysis of Intelligent Cargo and sustainability. The second part deals with the validation and demonstration of the suggested model.

The case studies as well as the literature studies revealed several issues in reaching sustainability of today's transport setups. First of all, freight flows are not monitored. Customer requirements for goods arrival times are not considered and shipments are moved based on schedules and routines. Lack of control leads to ambulance transports, which further decrease the degree of sustainability of the transport setup studied. Ecological accountability was not present anywhere in the transport system. Financial sustainability was perceived as difficult for the carriers, especially in Case Study II, due to their low margins.

Table 2 Matching the components of Smart Logistics System's framework with the environmental and financial sustainability

Component	*Environmental sustainability*	*Financial sustainability*
Collaborative logistics arrangement	Collaboration between competitors and contracts promoting high fill-rates are necessary components of an environmentally sustainable logistics system, avoiding the empty transports prevailing in the case studies.	Financial models promoting a high fill-rate rather than transport buyer policies will enable carriers to increase their operating margin above current levels.
Information sharing and enabling technology	Information sharing allows, e.g., data on different types of emissions to be transferred to the goods and thus to enable environmental accountability. Removing paper documents and sharing information electronically will reduce empty running and unnecessary, energy-costly stops in the transport process.	Costly manual information handling and errors caused by it can be reduced through information sharing, leading to lower operating costs. Sharing information will enable carriers to switch loads between each other and in that way reduce kilometres driven.
Decentralized information setup & Intelligent Cargo	With the shipments carrying information about themselves, it is possible to load emission data onto the cargo, keeping an environmental account throughout the transport process. Decentralized information makes it possible to load goods rules regarding the environment, e.g., what modes a shipment is allowed to travel by, whether the shipments are flagged for express delivery, etc.	Intelligent Cargo enables advanced rules regarding goods moving through the system, which can be used for differentiated cost models of transports, based on urgency, quality and environmental impact.

To be able to *explore how Intelligent Cargo can be used to control, track and reduce the environmental impact of goods transportation*, the requirements from the case study have to be analyzed and matched with the framework of components for the concept of the Smart Logistics System. Ecological accountability is assumed to contribute to environmental sustainability and they are both summarized in Table 2.

Validation prototypes

Two prototypes were built to validate and demonstrate the feasibility of the concepts derived from the literature and case studies. The prototypes were built in the logistics laboratory of Lindholmen Science Park (Gothenburg, Sweden). The laboratory holds an information infrastructure (based on Ericsson Open-SIS), a physical rig (including a full scale truck interior, goods and RFID tags and readers), a LSP/Carrier operator control room and a virtual reality road network, enabling test of large parts of the setup in Case Study I. Tests of the prototype showed a highly increased effectiveness in transportation operations through effective route planning, load consolidation, improved fill rates and yielded potential for an increased level of financial sustainability. The sharing enabled the actors to avoid execution hurdles and quickly respond to events in the transportation setup.

As a part of the second research project (Case Study II), a second version of the transport prototype was constructed and showed as a demonstration theatre at the ITS World 2009 Conference in Stockholm, Sweden. The original prototype was extended with Intelligent Cargo and ecological accountability and advanced freight handling rules to demonstrate the benefits and feasibility of using Intelligent Cargo to enable environmentally and financially sustainable and accountable logistics systems.

CONCLUDING DISCUSSION

Achieving environmental and financial sustainability is a huge challenge for the logistics industry and in particular for the transport operators, who face increasing pressure to improve environmental sustainability and at the same time face decreasing operating margins. This paper has not outlined a solution to these issues, but it suggests effective planning and control of transport operations enabled by the use and availability of information as a step toward achievinggreener logistics while at the same time improving profitability. The concept of *Intelligent Cargo to control, track and reduce the environmental impact of goods transportation* was derived from the literature and case studies. The testing prototypes showed the feasibility of implementations of this concept.

The main managerial contribution of this research is the demonstration of the feasibility of Intelligent Cargo as an enabler of improved environmental and financial sustainability. Anothercontribution is the confirmation of the theory from other authors that environmental efficiency goes hand in hand with resource efficiency.

The theoretical contribution of this paper is to identify how the concept of Intelligent Cargo and using decentralized information in transportation can benefit both environmental and financial sustainability as well as enable transport systems with environmentally accountable shipments. Several of the delimitations that have been outlined in the methodology sections can be considered interesting for future research, especially research on logistics models creating incentives for environmentally effective transports.

BIOGRAPHY

Henrik Sternberg (Corresponding author) is a Ph.D. candidate at the division of Logistics & Transportation, Chalmers University of Technology, Sweden. His research areas are waste in transport operations and advanced freight management systems. Before pursuing an academic career, Henrik was a consultant working in projects with e.g. Deutsche Post and Deutsche Bahn.

Andreas Hagen is a M.Sc. and a Ph.D. candidate at Chalmers University of Technology. His research area is Intelligent Transportation Systems, with focus on logistics infrastructure.

Paolo Paganelli graduated in Electronic Engineering at the University of Bologna in 1991. He was a research assistant at the University of Modena till 1993 and then worked for different ICT and consulting companies providing software tools for logistics and supply chain management. He has been involved in European Commission research programmes for over 15 years, leading projects on ICT-based innovations for logistics and other industrial sectors. In 2001 he became product manager of Gruppo Formula supply chain management solutions. Since 2006 he is Insiel's

head of Logistics Solutions. He is the coordinator of the European Integrated Project EURIDICE.

Prof. Dr. Kenth Lumsden is a full professor of “Integrated Transport Systems” at Chalmers University of Technology. Before this position he held professorships at different Swedish universities. Professor Lumsden has taken part in development and has been responsible for the start-up of a number of Swedish academic programs related to transport economics, transport technology and logistics. He has written textbooks on logistics and has been the principal author/ co-author of a number of conference, journal and research papers.

REFERENCES

Arnäs, P.-O. (2007) Heterogeneous Goods in Transportation Systems - A study on the uses of an object-oriented approach. *Department of Logistics and Transportation.* Gothenburg, Sweden, Chalmers.

Bartelmus, P. (2009) The cost of natural capital consumption: Accounting for a sustainable world economy *Ecological Economics,* 68, 1850-1857.

Björklund, M., Åstrand C. (2003) Environmental logistics - concepts and definitions. *Annual Logistics Research Network (LRN).* London, Conference Proceedings 2003.

Bowersox, D. J., Closs, D. J. & Stank, P. (2000) Ten mega-trends that will revolutionize supply chain logistics. *Journal of Business Logistics,* 21.

Brehmer, P.-O. (1999) Towards a Model of Lean Freight Transport Operations. *Logistics and Transport Systems.* Linköping University.

Eurodice (2009) Eurodice. Bologna, Italy, Insiel.

Halme, M., Hrauda, G. & Jasch, C. (2005) *Sustainable consumer services* London, Earthscan Publications Ltd.

Holmqvist, M. & Stefansson, G. (2007) Mobile RFID a case from Volvo on innovation in SCM. *Journal of Business Logistics,* 27, 251-272.

Kalantari, J. & Sternberg, H. (2009) Research outlook on a mixed model transportation network. *Journal of European Transport*, 62-79.

Litman, T. & Burwell, D. (2006) Issues in sustainable transportation. *International Journal of Global Environmental Issues,* 6, 331-347.

Lumsden, K. (2006) *Logistikens Grunder,* Lund, Sweden, Studentlitteratur.

Lumsden, K. & Stefansson, G. (2007) Smart Freight to Enhance Control of Supply Chains. *International Journal of Logistics Systems Management,* 3, 315-329.

McKinnon, A. C. (1995) Opportunities for Rationalising Road Freight Transport. London, Church House.

Nyquist, C. (2007) Improving Efficiency and Security in an Intermodal Transport Chain - With Focus on the Port of Gothenburg. Gothenburg, Chalmers.

Power, D. (2005) Supply chain management integration and implementation: a literature review. *Supply chain management: an International journal,* 10, 252-263.

Rodrigue, J.-P., Slack, B. & Comtois, C. (2001) The paradoxes of green logistics. *World Conference on Transport Research.* Seoul, Korea.

Ross, D. F. (1996) *Distribution Planning and Control,* Boston, MA, Kluwer Academic Publishers.

Schumacher, J., Gschweidl, M. & Rieder, M. (2009) Eurodice Mobile Agents Architecture for Distributed Intelligence. *ITS World 2009.* Stockholm, Sweden.

Stefansson, G. (2006) Collaborative logistics management and the role of third-party service providers *International Journal of Physical Distribution & Logistics Management* 36, 76-92.

Stefansson, G. & Sternberg, H. (2007) Smart Logistics Systems - SLS. *World Conference on Transport Research.* San Francisco, CA.

Stern, N. (2007) *The Economics of Climate Change: The Stern Review*, Cambridge University Press

Sternberg, H. (2007) Visual Planning: A Tool for Increasing Fill Rate in Logistics Distribution. IN SOHAL, A. (Ed.) *SCMIS.* Melbourne, Australia.

Sternberg, H. (2008) Transportation visibility and information sharing - a case study of actors' requirements. *World Review on Intermodal Transportation,* 2**,** 54-71.

U.S. Department of Transportation (2009) The 2007 Annual Motor Carrier Efficiency Study Report to Congress. Springfield, VA, Federal Motor Carrier Safety Administration.

Wackernagela, M. & Reesb, W. E. (1997) Perceptual and structural barriers to investing in natural capital: Economics from an ecological footprint perspective. *Ecological Economics,* 20**,** 3-24.

van Aken, J. E. (1978) On the control of complex industrial organizations. *Martinus Nijhoff Social Sciences Division.* Amsterdam, The Netherlands, University of Amsterdam.

Wu, H.-J., Dunn, Steven C (1994) Environmentally responsible logistics systems. *International Journey of Physical Distribution & Logistics Management,* 25.