IMPACT OF INFORMATION AND COMMUNICATION TECHNOLOGIES ON FREIGHT TRANSPORT AND LOGISTICS

Kapros Seraphim[*] *, Associate Professor*

Polydoropoulou Amalia, Associate Professor

Antonopoulou Maria, Researcher

University of the Aegean, Department of Shipping, Trade and Transport

Korai 21, Chios, Greece, 82100.

ABSTRACT

This paper assesses the impact of Information and Communication Technology (ICT) applications on the logistics performance. ICT offer significant possibilities for improvements in the transport systems efficiency, it is however quite difficult to estimate their "real" impact. Based on a field survey, the paper develops a model explaining the factors affecting the performance of freight distribution systems and the relative impact of ICT. The research is focused on operational characteristics of logistics. The pilot case particularly focused on the impact of a specific ICT category, this of "fleet and freight management" applications. The model examines the ICT impact on the average occupancy rate of vehicles, which represents a common standard objective of logistics optimisation. The model results show that the ICT use allows an increase of the average occupancy rate of vehicles by 5.176%. This impact is quite important, considering the strong competition in the freight transport and logistics sector.

[*] Corresponding author
E-mail address: skapros@aegean.gr

Key-words: Information Communication Technologies, logistics, freight distribution, transport modelling

1. INTRODUCTION

Freight transportation represents a key factor of socio-economic development. Freight traffic volumes have significantly increased over the last decades, as a result of radical changes in production and distribution systems on the one hand and structural economic and geopolitical changes on the other (Marchet et al, 2009). Changes in the production and distribution systems relate to the development of just-in-time methods and stock minimisation. These changes significantly affect the freight transport organisation and flow patterns; shipments are now more frequent, volumes per shipment are less massive, orders are more irregular, lead times are shorter and transport distances are longer (Kapros, 2009). Structural economic and geopolitical changes relate to the globalisation process, involving a significant increase of commercial exchanges, integration of new markets in the world economy, relocation of economic activities and new procedures, behaviours and user practices as well. Globalisation also affects the organisation of freight distribution systems and the flow patterns. Distribution networks are more extended and outsourcing practices are more intense. Freight traffic volumes are expected to further increase in the future (COM, 2007).

In this context, the management of freight transportation systems faces a great complexity. The creation of extended multi-firm networks involves a variety of actor types: shippers/producers, commercial companies, transport companies of all modes, third party logistics providers, intermodal transport operators, infrastructure operators. Transport users' quality requirements, such as reliability, flexibility and safety, have significantly increased. Considering the above, achieving high productivity and efficiency, lower costs and higher service quality in transportation, became an increasingly difficult task (Tsamboulas and Kapros, 2000).

In this framework, the field of logistics acquired a strategic importance. New logistics concepts have been developed, in order to respond to the new transport needs and find the right balance between different requirements. Beyond the management and optimisation of transport flows, logistics became a key-issue for the regulation and management of the whole production and commercialisation process of multi-firm networks (Bertolini, 2007).

Recent applications of Information Communication Technologies (ICT) can provide significant support to logistics planning. The “e-economy” concept is mainly supported by the new Information and Communication Technologies (ICT), which have the ability to transmit and receive information without regard to distance, at a relatively low cost (Rahman et al., 2006). ICTs may improve the potential benefits of supply chain management through reduction of inventory losses, increase of the efficiency and speed of processes and improvement of information accuracy.

New information technologies offer important improvement possibilities in transport and logistics, not only because flexible production and just-in-time systems need real time information and fast response, but also because they allow developing sophisticated tools (e.g. software applications that permit monitoring events across a supply chain – track & trace systems) with great potential in supply chain optimisation processes. They can bring customized supply chain solutions balancing between transportation, inventory/warehousing and other costs and service parameters. ICT contribute to reduce logistics costs and increase company competitiveness. Information technology providers currently offer a wider range of logistics applications such as information transfer, mode choice and routing, tracking and tracing, fleet optimisation, inventory management, claims management, booking, freight rate computation, reporting. Integrated applications are fundamental in order to provide real-time data across the supply chain and support dynamic decision-making (Tsamboulas and Kapros, 2002).

However, despite the rapid development and capabilities of information technology, it is not yet well known to which extend its applications actually influence the efficiency of distribution systems and the structure of freight flow patterns. Unfortunately, surveys of the industry suggest that the use of ICT is not widespread in the freight transport industry (Higginbottom, 2002).

The objective of this paper is to assess the impact of new technologies on the efficiency of freight distribution and logistics systems, at the company level. The research focuses on the operational characteristics of logistics chains. The paper firstly presents a literature review on the topic. Furthermore, it presents the organisation and results of a field survey. Based on the field survey results, the paper finally develops a model explaining the factors affecting the companies’ logistics performance.

2. LITERATURE REVIEW

Freight transportation represents a key issue in the economic and social development of a country and may be considered as one of the most important industries within the European economy. Over the last decades freight transportation in Europe has grown significantly, presenting an annual growth rate of 2,7% between 1999-2007. The total freight transport activity in 2009 is estimated to have amounted to 4228 billion tkm. Notably, the road transport share more specifically represents 45,6% of the whole traffic. The spectacular increase of freight traffic has stimulated an important growth of added value logistics activities (COM, 2009). The global logistics industry is estimated at roughly 13,8 % of the global GDP. Recently, the European Commission and national responsible authorities integrated the development of advanced logistics solutions in the transport policy agenda, considering logistics as an important tool of sustainable mobility (COM, 2006, 2007). At the same time, competition in the European logistics sector is intense. In this context, advanced ICT applications are viewed as a primary enabling tool for effective and efficient logistics systems.

The existing literature dealing with ICT applications in transportation and logistics is huge. It reveals many types of application, each one contributing on the transportation and logistics system with different way. ICT, named also Logistics Information Technologies (LIT), are a major component of the firm's investment, including hardware and software expenditures associated with logistics activities such as order, warehousing, inventory, and transportation management (Savitsikie, 2007). ICT applications started in the mid-to-late 1970s with Electronic Data Interchange (EDI) that allowed for a new form of chain management, as a first step before the development of various e-commerce applications (Allen, 2001). However, the high price and non-standardisation meant that there was a limited degree of implementation as it could only be afforded by large organizations. E-commerce refers to any form of economic activity that is conducted by electronic means between two parties including the exchange of information (Hesse, 2002). Various hardware and software applications were produced in the meanwhile, improving infrastructure, traffic and fleet management, facilitating a better tracking and tracing of goods across the transport networks and better connecting businesses and administrations (Giannopoulos, 2004). Among other, Radio Frequency Identification (RFID) has been proved as an efficient automatic identification and data capture technology (Sarac et al., 2009). And the list can be continuing even more.

Marchet et al. (2009) proposed a categorization about the main ICT applications available for freight transportation companies, in three application types: a) Transportation fleet and freight management, b) Supply chain execution and c) Field force automation. More specifically, transportation fleet and freight management applications have been essentially defined as decision support tools in transportation planning, optimization and execution. Applications help planners choose the transportation modes and also manage freight consolidation operations and coordinate company shipments. But also is being used as reporting tools by logistics managers who need to know vehicle travel times, service times, and the delivery points that were visited. Supply chain management applications are designed to manage and automate the flow of products through the entire transportation process and its phases. Specifically, they support functions related to information exchange and the field force automation applications, enabled by mobile technology provide an enormous opportunity for savings in operational costs and improvements in customer satisfaction, thanks also to higher integration between remote workforce and corporate business processes.

Existing research work dealing more particularly with the impact of ICT on transportation and logistics is less extended. It shows that logistics companies play a more important role than in the past as they coordinate and accelerate physical and information flows along multiple levels of the supply chain. With the rapid market changes, the whole logistics system has become more efficient and flexible. This has forced companies to look for accurate and real-time information on the status of the entire supply chain and distribution process to increase their planning capacity and to improve customer service levels (Sweeney, 2006). Banister (2004), proposes a classification into three categories for the possible impact of ICT on transport. a) the stimulation of more travel as new opportunities will become available, b) the substitution for travel as activities will be carried out remotely rather than by travel and c) the modification of travel as the two elements combine to change the ways in which activities are carried out. It has been identified that, the use of ICTs, is making possible the reduction of travel (Mokhtarian, 2004). ICT can be an enabler for front-end and back-end processing in a supply chain. Access to information by each of the party in a supply chain can make logistics services more accurate, swift and less costly (Pokharel, 2005). Since the supply chain involves several steps, the impact of ICTs in these can save costs at every step and at every interface between supply chain partners (Jayaraman, 2008).

According to the Third Annual Thematic Research – Freight Transport (2006), some software and information systems, can improve mobility and transportation management. By providing innovative services and creating favourable technical conditions for enhancing both the quality and the efficiency, while maintaining safety standards. A document about freight distribution management (European Commission DG Energy and Transport, 2009), identifies as best practise of improvement the innovative e-logistics. A number of ITS applications (e.g. web-enabled information and booking services, delivery notification and information through mobile phones, trip planning and resource optimisation, GPS-based vehicle location systems, long range, wireless communications, and others) enable the user to manage its logistics resources to realise flexible, demand-driven freights distribution schemes.

Davies eta al (2006) examined the extent to which Internet freight exchanges and the use of ICT processes are affecting general haulage, through a field survey focussing on UK. The main findings were that 85% consider ICT important for their companies; there was also a positive association between fleet size and the importance of ICT. 56% was using ICT for vehicle routing and planning, 33% for vehicle tracking and 13% for vehicle telematics. According to the responders opinion (69,2%), the freight exchanges can only be helpful in the area of less empty running. In all the other areas (such, choice of loads, reduce time to find backloads, reduce cost of finding loads, accuracy of information etc.) the usability wasn't confirmed. It concluded that when the industry structure is characterised by very large number of smaller operators, the adoption of ICT is least well developed and reliance on all more traditional means of operation is prevalent.

Bertolini (2007) analyses the impact of ICT on supply chain processes for a specific case of the Italian footwear industry. The main aim of the study was to quantify the current supply chain lead time (includes the hole process from manufacturing the product until it reaches the final customer) of the industry and to simulate the impact of adoption of ICT tools as a viable means to reduce the supply chain lead time. Using the "Process Breakdown Structure" (Hammer & Champy, 1993), each step labelled either as Value-Added (VA) or Non-Value-Added (NVA). The results for the current footwear industry showed that the amounts of VA activities and NVA ones were 32 and 9, respectively. In addition, VA and NVA activities required, respectively, 341 and 166 days to be performed, meaning that lead time for the whole process had that duration and the percentage of VA work was 67%. The adoption and use of ICT applications influences the supply chain activities. The amounts of time required (lead time) for VA and NVA activities were 334 days and 100, respectively. The percentage of VA work increased and reached 77%. The main findings were that advanced ICT tools have the potential to significantly reduce lead time of most of the logistics processes and that it can provide substantial improvements in the integration between the firms and its suppliers.

Interesting findings about the impact of ICT, by Sarac et al (2009) showed that RFID technologies can provide several advantages in supply chain management through better traceability and improved visibility of products and processes all along chains. Increase of efficiency and speed of processes, improvement on information accuracy, reduction of inventory losses are some of these advantages. Wang et al. (2007) also focus on how RFID can improve the information flow of a construction supply chain environment. Through the analysis of a dynamic model and the real time demonstration of RFID, concluded that this kind of software technology can significantly improve supply chain control and construction project management by improving the efficiency of operations and also by providing a dynamic control.

According to Ustundag et al (2009) Radio Frequency Identification (RFID) is regarded as promising technology for optimization of supply chain processes since it improves manufacturing and retail operations from forecasting demand to planning, managing inventory and distribution. A model was developed to measure how the product value, lead time and demand uncertainty influence the performance of integrated supply chain using RFID in terms of cost factors at the echelon level. The cost savings through the increased performance of supply chain were analyzed through simulation techniques. The expected benefits were calculated considering the factors of lost sales, theft, inventory, order and labour costs. The results showed that an increase of product value increases the total supply chain cost savings, and the increased demand uncertainty decreases the supply chain cost savings. It was also indicated that each member of the supply chain doesn't benefit equally from RFID integration. Increasing lead time decreases the total supply chain cost savings of the retailer.

De Jong et al. (2006) conducted a survey on the perception of users about the impacts of new technologies on urban distribution systems' performance. It has been pointed out that the use of ICT is expected to reduce the share of empty and not-fully-loaded vehicles. Developments in e-economy technology -when coupled with logistic innovations- can cause changes to the load factors. On the other hand, the use of technological tools could increase the use of small vehicle trips in the cities. De Jong et al developed a "4 steps" freight transport model incorporating the impacts of ICT in the generation, attraction, modal shift and traffic assignment processes.

Summarizing the literature review, important research is done on the impacts of ICT on transport and logistics at a conceptual and theoretical level. In addition, important research work deals with impact assessment using "overall" firm's performance indicators, without entering into the operational and technical characteristics of logistic systems. Finally, research work explaining the impact of new technologies with measurable indicators at the operational logistics level is limited, but of high importance for future research activities.

3. PILOT FIELD SURVEY

3.1. Basic assumptions and data collection methodology

The field survey is focused on the impact of new information technologies on freight distribution systems' performance. The sample consists in three actor types: shippers/producers, commercial companies and forwarders/third party logistics providers. In total, 98 firms answered the questionnaire which represents the 19% of response rate. Among the various categories of ICT presented in this paper this pilot field survey is specifically focused on transportation fleet and freight management applications (Marchet et al. 2009).

The data collection was based on a structure questionnaire. The questionnaire was filled in either by phone, registering the answers in special software (WinMint), or by forwarding the questionnaire to companies via e-mail or fax, and registering the complete form afterwards. The structure of the questionnaire is as follows:

> Part A: Firm characteristics: type of firm, sector, type of product, scope of operation, turnover, etc.
> Part B: Characteristics of transport activities of the firm: outsourcing, vehicle ownership and use of transport and logistics planning software.
> Part C: Transport chain characteristics: e.g. origin, destination, distance, time constraints, frequency, value, weight, fleet size, full or consolidated loads, occupancy rate, outbound and return loads, routing configuration and number of stops.

To develop an appropriate model, the objective of the questionnaire was to collect data related to operational factors on which freight distribution efficiency and service quality largely depends. Such factors are the occupancy rate of vehicles used, the rate of empty returns, the lead time (time between order and delivery), path characteristics (e.g. number of stops during a delivery round trip). To assess the operational performance of logistics systems, these factors should be examined considering objective data of the company (e.g. fleet size) and regular demand characteristics (e.g. total freight volumes, average shipment size). The analysis of this data set should provide an overall picture on the capabilities of the company to achieve economies of scale, productivity of vehicle fleet and rationalization of resources with high quality of service. The later are key issues of logistics optimisation process.

Finally, the questionnaire collects data on the actual influence of new technologies on the factors affecting the efficiency of logistics systems. Emphasis is given on combined technological tools optimising route choice, fleet productivity and inventory management. A detailed report and update of these technologies and systems, was included in the questionnaire.

3.2 Descriptive Statistics

The field survey provided a data set with 98 observations. The fifty one observations were from Greek companies and the other forty seven from other countries of the European Union. Twenty one questionnaires were field up by companies in Netherlands.

Table 1 presents the sample composition according to company type. Manufacturers and primary producers represent the 19% of the total. On the other hand 36% were logistics service providers.

Table 1-Company type

	Frequency	Percent
Manufacturer / Primary producer	19	19,4
Commercial Company	43	43,9
Logistics and transport service provider	36	36,7
Total	98	100,0

Table 2 presents either the product is intended to be used by other companies (retailers) or end-users (consumers). Most of the products that are being transport are going to other companies for further elaboration (78%).

Table 2-Product use

	Frequency	Percent
Companies (retailers)	77	78,6
End users (consumers)	21	21,4
Total	98	100,0

Table 3 presents the geographical range of the firms' activity. The scope of the companies in 42% of the cases is national and only 4% is local. But there are quite few companies that have global range of activities (21%).

Table 3-Company's geographical range

	Frequency	Percent
Local	4	4,1
Regional	12	12,2
National	42	42,9
Pan-European	19	19,4
Global	21	21,4
Total	98	100,0

Table 4 presents the company choices about operation or outsourcing transport activities. Most of the firms operate completely internally their activities in 48%, while only 11 of 98 firms interviewed completely outsource their activities to transport logistics services.

Table 4- Companies choices about operation or outsourcing transport activities

	Frequency	Percent
Completely outsourced	11	11,2
Partially outsourced	40	40,8
Completely handled internally	47	48
Total	98	100,0

More than half of the companies use their own transport means, 67%, where the other 33% hire carriers or logistics providers when they need it.

Finally, the survey revealed a great diversity of total distances travelled by vehicle round trip. Distances vary from 10 km (cases of final delivery from private or public urban distribution centres) to 1500 km (cases of inter-urban distribution flows). Most of respondents however operate in distances between 100 km and 250 km.

The results of a descriptive statistics analysis are presented in the following Table 5, for the variables that are used in the below model.

Table 5-Descriptive Statistics

Description	Minimum	Maximum	Mean	Std. Deviation
Average occupancy rate (%)	60	100	80,01	14,03
Lead Time (hr)	1	336	37,18	49,20
Total Weight (tones/weekly)	1	600	97,56	151,78
Average shipment size (tones)	1	40	10,28	12,41
Distance travelled with empty vehicle (% km)	1	100	22,55	24,77
Number of Vehicles	1	75	2,84	8,52
Number of Stops	1	50	5,34	8,74

The sample includes a significant range of company size, from very small (1 vehicle) to medium (75 vehicles). The results show quite satisfactory average occupancy rates for the companies of the sample, ranging from 60% to 100%, independently on the fleet size and the total freight volumes. Lead times (time between service order and delivery) largely varies from one hour to fourteen days. This is explained by the variety of commodity types and the diversity of logistics requirements of various commodities. The number of stops of the typical round trip also varies significantly, from origin-destination direct transport to complex itineraries involving up to 50 stops. The shipment size also varies from 1 tone to 40 tones (in case vehicles achieve a 100% occupancy of their capacity). This is in alignment with the general trend to reduction of average shipment size, explained by the stock minimisation and just-in-time delivery trends. It is further influenced by the share of "last mile" delivery cases included in the sample, taking into account the constraints to achieve economies of scale in urban areas. The results reveal a significant diversity of logistics organisations, related to different company types and company sizes.

The data set also includes a number of dummy variables. Their descriptive statistics are presented in the Table below.

Table 6-Frequencies of dummy variables

	Frequency	Percent	Valid percent	Cumulative percent
Country (Greece)	51	52	52	100
Country (Otherwise)	47	48	48	48
Firm Type (shipper/ producer)	30	30,6	30,6	100
Firm Type (otherwise)	68	69,4	69,4	69,4
Use of technology	63	64,3	64,3	100
No use of technology	35	35,7	35,7	35,7

Table 6, presents the frequencies of the countries and the type of the companies. 51 observations concern Greece and the other 47 relate to western European countries. The sample is composed from 30 shippers-industrial producers and 68 companies of the 3rd party logistics sector (forwarders/logistics service providers).

4. MODEL DEVELOPMENT AND ESTIMATION RESULTS

Based on the collected data, the development of a model might allow a deeper analysis and explanation of the new technologies impact on freight distribution. The model development is based on linear regression techniques, which allow a meaningful exploitation of continuous variables.

The average occupancy rate of vehicles is defined as dependent variable, since maximisation of occupancy rates is a common standard objective of any logistics optimisation process, independently on the context. The other data types collected represent the independent variables. Through the linear regression techniques, it was attempted to identify and estimate causal relationships. More specifically, the independent variables are: average shipment size, lead time, total cargo weight per week, the percentage of km travelled with empty vehicle along a round trip, the number of stops along a round trip, the number of vehicles used, the dummy variable of use of new technology (software optimising route choice, fleet productivity and inventory management; 1=use of new technology, 0=otherwise), the dummy variable of firm type (1 = shipper/industrial producer, 0 = otherwise) and the dummy variable of countries (1 = Greece, 0 = other country).

The model results are presented in the following table.

Table 7-Regression model of average occupancy rate (% volume)

Variables (units of measurement)	Model	
	B	t-statistic
Constant	73.473	22.644
Lead Time (hr)	0.194	3.694
Total Weight (tones)	0.011	1.640
Average shipment size (tones)	0.019	1.522
Distance travelled with empty vehicle (% km)	-0.007	-1.335
Number of Vehicles (fleet size)	0.198	1.310
Number of Stops along a round trip	-0.044	-0.302
Dummy variable of ICT use (1 = use, 0 = no use)	5.176	1.621
Dummy variable of firm type (1 = producer, 0 = otherwise)	4.019	1.407
Dummy variable of countries (1 = Greece, 0 = otherwise)	-3.952	-1.384
Model Summary		
Number of observations	98	
R2	0.323	
Adjusted R2	0.254	

The constant variable of the model is 73.473 and represents the average occupancy rate of vehicles in percentage (%) if all independent variables were zero. Taking into account the market conditions and practices, the value of occupancy rate is considered quite satisfactory, even without support of new technology.

If all other independent variables are unchanged, the use of new technologies allows an increase of the average occupancy rate of vehicles by 5.176%. Without being spectacular, the new technology impact is however important. In certain markets, its importance might be crucial, taking into account the strong competition in the freight transport and logistics sector.

Among the other independent variables, the type of company clearly affects occupancy rates; in case producers perform own account transport instead of outsourcing, it is because their production systems and markets allow a regular traffic of high volumes and a pre-selected strategy for own account transport is based on certainty of high fleet productivity. The country of reference also affects the model results; the model reflects the weak ICT penetration in the Greek market, compared to companies of Western

Europe. Therefore, in the case of Greek companies, the average occupancy rate is lower.

Finally, it is obvious that the variables “number of stops” and “distance travelled with empty vehicles” along a round trip negatively affect the average occupancy rate. In the case of the first variable, the increase of number of stops gradually decreases the average occupancy rate at a round trip basis. The distance travelled with empty vehicles mainly refers to empty returns, being one of the most important problems in logistics and transport network organisation. However, as Table 7 shows, the relative weight of these variables is very limited. This can be explained by the fact that most of the companies questioned have already optimised their spatial network configuration to a great extend.

5. CONCLUSIONS AND FUTURE RESEARCH

Despite the important development and diffusion of new information technologies, it is not yet well known the impact they have on freight transport and logistics performance. This paper attempted to examine the impact of new information technologies in the case of freight distribution systems. The research is focused on operational characteristics of logistics, mainly related to “technical” or “physical” aspects of transport chains. It undertook a pilot field survey in order to collect appropriate data for a model development. The pilot case particularly focused on the impact of a specific ICT category, this of “fleet and freight management” applications. The methodological framework follows an approach at the level of “transport chain”, at which up to now research findings are quite limited. The model development is based on linear regression techniques, which allow a meaningful exploitation of continuous variables.

The model examines the impact of these ICT applications on the average occupancy rate of vehicles, which represents a common objective of all actors involved in the transport market and provides one of the most meaningful –and emblematic- expressions of logistics optimisation, independently on the context. Except for the use of a new technology (tools optimising route choice, fleet productivity and inventory management), the other independent variables of the model are: average shipment size, lead time, total cargo weight per week, percentage of km travelled with empty vehicle along a round trip, number of stops along a round trip, number of vehicles used, firm type and country.

The model application finds out that the use of new technologies allows an increase of the average occupancy rate of vehicles by 5.176%. This impact is not as spectacular as possibly expected taking into account various theoretical considerations, however it is really important. In certain transport market segments, its importance is considered as crucial, taking into account the strong competition in the freight transport and logistics sector.

The model results are in line with the main theoretical findings of the literature review. ICT technologies have positive impact on load factor (average occupancy rates of vehicles) and consequently, on fleet productivity and logistics efficiency and performance.

The added value of this research consists in one of the very first attempts of the scientific literature to estimate the impact of ICT in quantitative terms, at the operational level. Despite the shortcomings of this attempt (heterogeneous sample, diversity of vehicle and fleet sizes, heterogeneous geographical markets, diversity of average distances travelled etc) the findings however provide an indicative magnitude of impact from ICT use on occupancy rates of vehicles.

The first results are encouraging for further extending this survey in the near future by enlarging the sample and including additional ICT application categories. A comparative analysis of future results, namely between impacts of different ICT applications, between actor types, between market segments etc, is expected significantly lighten various unknown aspects of the problem.

ICT offers solutions, but the level of adoption is low, except for very large companies. Companies should have easy access to ICT solutions. Closed systems entail start up costs both in terms of technology and software.

REFERENCES

Allen, S. (2001) 'Leveraging procurement: the quiet e-business', Logistics and Transport Focus, May, 29–30.

Banister D. and Stead D. (2004) 'Impact of information and communications technology on transport', Transport Reviews, Vol. 24, No. 5, 611-632.

Bertolini M., Bottani E., Rizzi A. and Bevilacqua M. (2007) 'Lead time reduction through ICT application in the footwear industry: A case study', International Journal of Production Economics, 110, 198-212.

Davies I., Mason R. and Lalwani C. (2006) 'Assessing the impact of ICT on UK general haulage companies', International Journal of Production Economics, 106, 12-27.

De Jong G., Algers A., Papola A. and Burg – Kessel R. (2006) 'Impact of the e-economy on traffic and traffic-related indicators in urban areas', 85th TRB, Annual Meeting.

European Commission (2006) 'Freight logistics in Europe – key to sustainable mobility'.

European Commission (2007) 'Freight transport logistics action plan'.

European Commission DG Energy and Transport (2009) 'Freight Transport', Thematic Research Summary, Transport Research Knowledge Centre.

European Commission (2009) 'Energy and transport in figures', Statistical pocketbook.

Evangelista P. and Sweeney E. (2006) 'Technology usage in the supply: the case of small 3PLs, International Journal of Logistics Management, Vol.17, No. 1, pp. 55-74.

Giannopoulos G.A, (2004) 'The application of information and communication technologies in transport', European Journal of Operational Research, 152, 302-320.

Hesse Markus (2002) 'Shipping news: the implications of electronic commerce for logistics and freight transport', Resources Conservation and Recycling 36, 211-/240, Elsevier.

Higginbottom D, (2002) 'Digital tachographs a challenging change', Logistics and Transport Focus, December, 39–41.

Jayaraman V., Ross A. and Agarwal A. (2008) 'Role of information technology and collaboration in reverse logistics supply chains', International Journal of Logistics: Research and Applications, Vol. 11, No. 6, 409-425.

Kapros S (2009) "La logistique", *Questions-clefs pour l'Europe des transports*, M. Savy (ed), La Documentation Française.

Marchet Gino, Alessandro Perego and Sara Perotti (2009) 'An explanatory study of ICT adoption in the Italian freight transportation industry', Department of Management, Economics and Industrial Engineering, Italy.

Mikko Karkkainen, Sanna Laukkanen and Sami Sarpola (2006) 'Roles of interfirm information systems in supply chain management', Department of Industrial Engineering and Management, Department of Business Technology, Helsinki University.

Mokhtarian P., (2004) 'A conceptual analysis of the transportation impacts of B2C e-commerce', Transportation 31, 257-284.

Nandiraju S. and Rugan A. (2004) 'Freight transportation electronic marketplaces: A survey of market clearing mechanisms and exploration of important research issues', Institute of Transportation Studies, Department of Computer Science and Department of Civil & Environmental Engineering, University of California, TRB.

Pokharel S., (2005) 'Perception on information and communication technology perspectives in logistics', The Journal of Enterprise Information Management, Vol. 18, No. 2, 136-149.

Polydoropoulou A., Baker M., Ben-Akiva M., Kitrinou E., Mindali O., Rahman A. and Salomon I. (2003) 'Factors affecting the impact of e-economy on transport', Aegean Working Papers Issue 1.

Rahman, A., A. Polydoropoulou, and M. Ben-Akiva (2006) 'Predicting the Impact of E-economy on Transport (POET): Project Description and Final Conclusions.' Paper Presented at the *85th TRB Meeting*, January 22nd-26th, Washington DC.

Sarac A., Absi N., Dauzere-Peres S (2009) 'A literature review on the impact of RFID technologies on supply chain management', Working paper ENSM-SE CMP WP.

Savitskie Katrina (2007) 'Internal and external logistics information technologies', Department of Marketing and Supply Chain Management, University of Memphis, Memphis, USA.

Tsamboulas, DA, Kapros, S. (2000), "Decision-Making Process in Intermodal Transportation", *Transportation Research Record No 1707*, pp. 86-93.

Tsamboulas D., Kapros S. (2002) 'Impact of E – Economy on Traffic Patterns', Proceedings of the Conference "*Globalisation, E-Economy and Trade*", STELLA Network (Sustainable Transport in Europe and Links and Liaisons with America), Sienna, 7-9 June.

Ustundag A. and Tanyas M. (2009) 'The impacts of Radio Frequency Identification (RFID) technology on supply chain costs', Transportation Research Part E, vol. 45, 29-38.

Wang L.C., Y.C. Lin, and P.H. Lin. (2007) 'Dynamic mobile RFID-based supply chain control and management system in construction', Advanced Engineering Informatics, 377-390.