

ICTs Contribution to Global Logistics Sustainability

Ruth Carrasco-Gallego¹, Ana Moreno-Romero¹

¹ Escuela Técnica Superior de Ingenieros Industriales, Technical University of Madrid (UPM), C/José Gutiérrez Abascal, 2, 28006 Madrid, Spain
ruth.carrasco@upm.es, ana.moreno.romero@upm.es

Abstract. This paper addresses the economic and environmental sustainability of global supply chains. A main challenge posed by global supply networks is a substantially increased demand for long-distance freight transport services, which results in externalities such as emissions of greenhouse gas and other atmospheric pollutants. The contribution of ICT to mitigate the environmental impacts of global supply chains is explored, focusing the discussion on containers intermodality and on the use of smart tagging for closing material loops through product reuse and materials recycling.

Keywords: global logistics, information systems, intermodality, container terminal, reuse, recycling.

1 Introduction: General Framework, Objectives and Methodology

This paper is the result of the authors' participation in a study promoted by the Real Academia de Ingeniería (RAI) (Spanish Royal Academy of Engineering) entitled "The contribution of ICTs to transport sustainability in Spain". The study examines the potential of Information and Communication Technologies (ICTs) in helping to mitigate the serious problem of lack of sustainability (especially environmental) in the current transport model. Furthermore, it intends to encourage debate among the administrations, universities and companies involved in this sector on the need to innovate in the search for solutions to this problem and to reflect on the role that engineering education plays in this area.

The study is a collaboration between the *RAI*, companies and different public institutions, with a group of specialists' contributions, which have been selected and directed by a Managing Committee made up of academics and representatives from some of the participating entities. A total of 62 experts (13 academicians from the RAI, 13 university professors, 11 representatives from public administrations and 25 professionals from the ICT and transport sectors) from different disciplines have contributed to this study. During the 11 months of work, from the end of 2008 until the end of 2009, numerous interdisciplinary discussion meetings and three global encounters were held with the purpose of allowing each of the participants to contribute from his or her experience and from the triple perspective – economic, social and environmental – of sustainability.

The study examines, on the one hand, how the use of ICTs can directly impact mobility patterns of people and cargo. First, ICT-enabled services, such as advanced collaboration tools and teleworking, electronic banking, distance learning or telemedicine, have provided citizens with access to a wide variety of services, without having to increase the need for “transport production”, with its subsequent externalities (emission of greenhouse gases and other pollutants, noise, accidents, traffic congestion). It is a question of reconciling physical presence, when it is necessary, with a reduction in superfluous movement. Second, the “dematerialization” of certain goods (digitalization of periodicals, books, audiovisuals, etc.) reduces the need for transport tied to hardware (paper, CDs, videos, etc.) as content migrates to a digital format. On the other hand, given the current mobility patterns, the study also examines how ICTs can contribute to achieving more efficient journeys, improving the performance of vehicles and infrastructures and managing the traffic of people and cargo to obtain safer, more energy efficient and less environmentally impacting transport systems (Pérez Arriaga and Moreno Romero, 2009).

After presenting the general framework of this research and the methodology used, we will concentrate on the primary aim of this paper, which is twofold:

- The first objective is to identify the main challenges currently faced by global logistics systems from the sustainability point of view, and mainly from the economic and environmental perspectives.
- The second objective is to explore how ICTs can help to mitigate the environmental impact of global supply chains. We will present concrete examples focused on containers intermodality and on the use of smart tagging for facilitating product reuse and materials recycling.

The remainder of the paper is structured as follows: section two discusses the sustainability of global supply chains, especially from the economic and environmental perspective. The discussion is continued in section three, where different freight transport modes are compared from the environmental point of view. Section four presents various ways that ICTs can contribute to reducing environmental impact in global supply chains. We focus on applications dealing with freight transport systems (maritime containers) and on the use of smart tagging for reuse and recycling processes. Finally, the conclusions of this paper are presented in section five.

2 Global Logistics and Sustainability

World trade, and along with it, the demand for international freight transport, have been growing in the last few decades at a higher rate than the world economy. According to the World Trade Organization (WTO, www.wto.org), while the world GDP has multiplied by eight since 1950, international trade has multiplied its volume by twenty-seven. As a consequence, international trade represented 20.5% of the world GDP in 2006 as opposed to 5.5% in 1950. This expansion of international trade has logically been accompanied by a spectacular growth in international freight transport (Figure 1). In the last two decades, we have seen a progressive distancing of manufacturing locations in relation to consumption areas and the shift in world

commercial routes toward the Asian continent, caused by the greater commercial opening of countries like China and because of the specialization of these countries in manufacturing consumer goods that are then exported to other areas of the world.

Not only finished products, but also frequently parts and intermediate products are transported in this global movement of materials. This is a consequence of the development of global supply networks, in which various actors, sometimes separated by thousands of kilometers, take part in the manufacture of a product. The global process of producing a product can be broken down into various stages (“disintegration of production”), in such a way that the manufacture of parts or subassemblies that make up the product may take place in different countries and then they are transported to the location where the final assembly takes place.

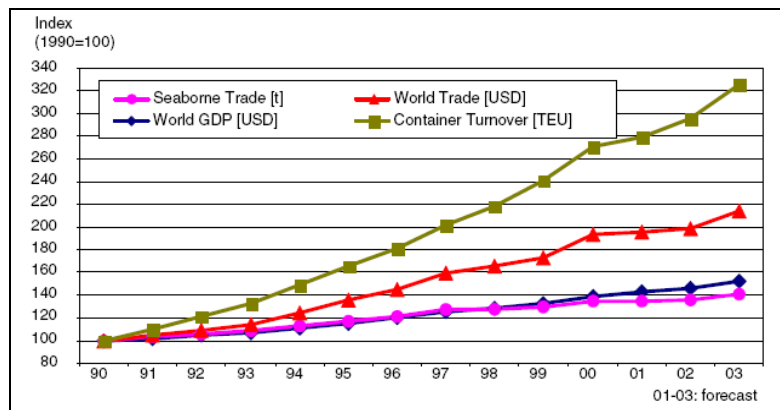


Fig. 1. Growth of world trade and container turnover in relation to world GDP. Source: Steenken et al. (2004)

The importance of cargo transport as an economic sector and its historical contribution to the development of regions and the progress of society is obvious and unquestionable. Nevertheless, growing social concern over the environment raises doubts about the sustainability of our current production-distribution models. The rapid growth of freight transport has also caused an increase in CO₂ emissions and related atmospheric pollution. In spite of improvements made in the different transport modes in terms of energy efficiency and the slow introduction of non-fossil fuels, greenhouse gas emissions associated with carriage of goods have continued to grow, due to the increasing demand for transport services. This increasing demand is, to a certain extent, a consequence of the disparity between transport services and their real cost. The non-internalization of environmental costs that are generated by freight transport favors the decision to locate production centers far from points of consumption, as well as the manufacture of different parts and components in geographically dispersed locations. Regarding this, it should be pointed out that greenhouse gas emissions originating from international transport by air or sea are not taken into account in international regulatory instruments for climate change, such as, for example, the Kyoto Protocol, at this time. New binding agreements regarding international transport emissions were not reached at the recent Copenhagen Climate Conference.

3 Freight Transport: Modes, Intermodality and Sustainability

Transport is a great energy consumer, especially of energy from fossil fuels. Currently, in Spain, transport (of people and cargo) is the sector that consumes the most energy (39%), even more than industry (31%) (IDAE, 2005). Given the fact that the majority of energy used in transport comes from petroleum, this sector is responsible for approximately one fifth of world energy-use related CO₂ emissions, only surpassed by generation of electricity (40%) (IEA, 2006). However, not all modes have the same impact nor are they all appropriate for transport of the same type of products. The modes with a lower load capacity, such as road or air transport, have a greater energy consumption per tonne-kilometre than railway, waterborne transport or by pipeline. But, on the other hand, air and road transport provide the operator with lower fixed transport costs, as well as speed (air) and flexibility and capillarity (road) which is not presently the case with the other means of transport. The reader is referred to chapter 7 in Pérez Arriaga and Moreno Romero (2009) for delving into this comparison. The interdisciplinary discussions held during RAI study, which included distinguished representatives of aeronautical, naval, mechanical and civil engineering in Spain, provided the base for this mode (vehicles and infrastructure) comparison, which is centered in modes energy efficiency.

Intermodality enables the use of the most adequate means in each of the legs of a journey, reducing energy consumption and along with it, the environmental impact of a particular transport service. The development of intermodality requires, aside from standard cargo containers, coordination between the different agents participating in the logistics process which is only possible through the use of ICTs.

4 The Role of ICTs in the Sustainability of Global Logistics

The introduction, implementation and use of ICTs in logistic companies is usually motivated by an attempt to reduce costs. The objective is to obtain a more efficient freight transport, that consumes less resources in terms of fuel, labor, space, etc., while maintaining or even improving the level of service provided to the customer (doing more with less). This search for cost savings has a positive indirect effect on the environment.

How can ICTs contribute to improving the sustainability of global logistics? In the RAI study three central themes of action were identified:

a) Facilitating communication and coordination. The development experienced by ICTs in the last few decades has meant a reduction of the marginal costs of international communications to almost zero and has provided tools that facilitate the coordination of processes linked to the management of global supply networks. ICTs also facilitate the coordination between the agents that participate in intermodal cargo transport.

b) Optimizing. The ever-growing processing capacity of computers today and the increasing implementation of information systems in manufacturing and commercial processes, has enabled a widespread use in business of combinatorial optimization tools, such as routing and load optimization software. This type of software, based on

techniques of operational research, attempt to reduce the number of kilometres necessary to carry out a particular distribution plan or to provide load configurations which take advantage of the space available on a pallet, in a maritime container or a truck cargo space. Thus, reducing the number of kilometres necessary and making better use of available space means that the same volume of goods can be distributed utilizing fewer resources, which is obviously to the advantage of sustainability in distribution systems.

c) Locating and identifying articles in real time. The extension of applications based on systems of navigation and positioning by satellite to civil uses (GPS and, in the future, Galileo) and the spread of radio frequency identification systems (RFID) have allowed the development of new logistics management tools, such as fleet management systems or systems of remote control of rolling stock on the railway. These tools contribute to improving the management of logistics flows which indirectly reduce the environmental impact of freight transport. Likewise, product tagging with bar codes or RFID can be very useful for product end-of-life management processes.

In the following two subsections some more concrete examples of how diverse applications of ICTs contribute to making global logistics more efficient will be presented.

4.1 ICTs for Maritime Containers Intermodality

4.1.1 Technologies for the Automatic Identification and Tracking of Cargo

Using identification technologies to avoid manual input of data in the system is a key element for a tracking system to be reliable. A technology that has been used successfully for this purpose is the bar code. Nevertheless, and especially in the case of load handling elements (intermodal containers, pallets, etc.), there are other automatic identification and tracking technologies which may be of interest, such as GPS, RFID or OCR.

The use of GPS receivers in intermodal containers permits tracking the location of a container throughout the different stages of its journey, regardless of whether the vehicle that is transporting it is equipped with another receiver. However, the stacking of containers in intermodal terminals and the margin of error of the GPS signal (around a few meters) limit its use presently for identifying the exact position of a container in a terminal. An alternative in this case is identification by radio frequency (RFID), a technology that determines the “identity” of an object automatically (a container, a vehicle, a port crane) to an information system, similarly to the way a barcode would, but without the need to establish direct “line-of-sight” contact between the RFID tag and the scanner. The RFID tag can be used to identify the container itself, the support element (crane) that is handling it or the vehicle that comes to the terminal to take the container away.

Optical Character Recognition programs, which recognize a text from an image of it and transform the pixels of the image in a format which is comprehensible for other computer applications, such as ASCII or Unicode, are also being used more and more frequently. ISO containers are unmistakably identified by a serial number engraved

and clearly visible on its exterior. If load handling elements equipped with a digital camera and an OCR program are used, it is possible to automatically identify the specific container on which a certain operation is being performed and send that information telematically to the control center of the terminal to be registered.

These three automatic identification technologies are not by any means separate elements, but rather complementary. For instance, it is possible to utilize GPS to track a vehicle that is transporting a container (ship or truck cab) in real time, RFID to detect which crane is moving it and register in what space of the terminal it is deposited and OCR to identify the serial number of the specific container on which these operations are being performed.

It should be noted that container tracking is an essential element of the “nervous system” in the body of the intermodal freight transport system. Real-time and reliable information about the location and status of freight units is a basic element in the coordination of the different agents participating in an intermodal transportation process (shipping lines, truck and rail companies, terminal operators, clearing & forwarding agents, etc.). Quantifying the impact of container tracking systems in the economical and environmental performance of global supply chains is a complex issue, as the metric should reflect the enabling-role of container tracking on intermodality coordination. An example on how this measurement could be achieved is provided in Hengst and Sol (2002), who attempted to quantify the impact of ICT-enabled interorganizational coordination in the container-transport industry. Through a simulation model fed with an extensive real data set from a large shipping line in the port of Rotterdam, they showed statistically significant differences in the performance (measured in terms of cost, time and environmental effects) of two possible situations: a situation with poor interorganizational coordination and a situation with enhanced coordination enabled by ICT support. Their simulation also showed that improvements were higher for long-distance transports (≥ 750 km) than for short-distance transports.

4.1.2 Combinatorial Optimization in Port Terminals

The Travelling Salesman Problem (TSP), the Bin Packing Problem (BPP) or the Vehicle Routing Problem (VRP) are some basic models of combinatorial optimization widely applicable in logistics systems. Thanks to the computing capacity available today, it is possible to find the optimal or a near-to-the-optimum solution to certain instances of these problems in short computational times. Commercial software for route or load optimization use model types VRP or BPP to represent real logistical situations. They typically use heuristic algorithms for finding a solution that, without obtaining the mathematically optimal solution, provides good solutions, habitually better than when the problem is solved “by hand”, in a short calculation time. This type of computer tools have allowed obtaining significant savings in the distances travelled by vehicles and in the number of vehicles necessary to carry out a distribution plan, since they take better advantage of the load capacity.

Likewise, present day information systems permit the application of many of these optimization techniques in daily operations at port terminals, while decision making is updated almost in real time. For example, the optimal sequence in which a shipping container should be unloaded or the route that should be followed by the crane in order to minimize the distance traveled are calculated at the control center of the

facility. These instructions are transmitted in real time to the automatic equipment or to the person that has to carry out the operation, generally through wireless communications systems (radio frequency, WiFi, mobile communications). Steenken et al. (2004), and its further update in Stahlbock and Voss (2008), constitute two good reviews of the state of art on optimization in port terminals.

4.2 Intelligent Tagging for Closing the Loop

ICTs, and particularly “intelligent” tagging of products (with RFID or some type of barcodes) can enormously facilitate the processes of recycling and reuse which are characteristic of reverse logistics. This link between ICT and product’s end-of-life management remains quite unexplored either in the academic literature and in practice. However, some interesting examples are provided in the reminder of this section.

Saar and Thomas (2003) explore how RFID and bar codes can increase the efficiency in the recycling and reuse industries, in the same way that efficiency was increased in the retail sector in the 80s by the introduction of bar codes. For instance, tags on used products can enable rapid sorting in the recycling processes. Tags on equipment products can also link to remote databases where products disassembly instructions become available for the recycler. Batteries constitute an example of the first application (rapid sorting). Typically, many kinds of batteries are collected together. Bar codes or RFID tagging can enable rapid sorting of batteries in order to send them to different smelters. An example of the second application (link to dismantling instructions) is electronic equipment. Product manufacturers or an industry-wide consortium can develop dismantling instructions per manufacturer and model that can be linked to a tag attached to the product. The instructions can indicate the recommended dismantling sequence for the product, which parts have a greatest recoverable value or how specific hazardous components should be removed.

Klausner et al. (1998) and Simon et al. (2001) provide concrete examples on how intelligent products tagging can be used to facilitate parts reuse in domestic appliances. This type of equipment typically includes some particular parts, such as motors, whose lifetime exceeds the lifetime of the product using it. These components are also usually one of the most expensive parts of the product, so they show a good potential for reuse. However, manufacturers need to determine the state of the reusable part when the discarded product is dismantled in order to determine whether the used part is suitable for reuse or not. For such a purpose, an electronic data log (EDL) is to be added to the product. This system consists of a simple non-volatile memory and the corresponding communications link. During the use phase of product lifecycle, the EDL records data about the usage pattern of the appliance. At the end-of-life phase, the dismantled motor equipped with the EDL can be queried in order to extract the recorded information, which helps manufacturers to discern which parts have been heavily used and are presumed to be worn out and which parts have had a light usage and show potential for reuse. A real example on motors reuse in electric drills at Bosch is described in the paper by Klausner et al. (1998). Simon (2001) reports a similar experience in the UK for washing machines.

5 Conclusions

The boom in international trade and the development of global supply networks has substantially increased the demand for long-distance freight transport services. However, in the discussion about freight transport and sustainability, a first reflection arising in the interdisciplinary study carried out at RAI was centred on the long-term durability of our present production-distribution models, mainly based on global supply chains. Currently, greenhouse gas emissions originating from international transport by air or sea are not taken into account in international regulatory instruments and commitments related to the Kyoto Protocol, given the complexity of assigning emissions to a particular country. The rapid growth of cargo transport has meant an increase in CO₂ emissions and other atmospheric pollutants.

Aside from facilitating intermodality, the application of ICTs to logistics systems has allowed reducing inefficiencies and optimizing processes in all stages of freight transport. Automatic identification tools (such as barcodes, RFID tags or OCR software), optimization programs (route or load optimization software, for example), satellite navigation and positioning systems (GPS) or mobile communications systems (GSM, GPRS and UMTS) facilitate the development of new logistics processes, which attempt to reduce costs through better use of available resources (fuel, labour, space, etc). This search for cost savings indirectly, but positively, impacts on the environmental sustainability of logistics systems. Likewise, product smart tagging with RFID or barcodes can facilitate more efficient end-of-life management processes for some products.

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