TRANSPORT PROBLEMS 2014
PROBLEMY TRANSPORTU Volume 9 Special Edition

TEN-T corridor; European rail freight; IT systems

Phil MORTIMER
NewRail – Centre for Railway Research, Newcastle University
School of Mechanical and Systems Engineering
Stephenson Building, Newcastle upon Tyne NE1 7RU, United Kingdom
João RIBEIRO*
Instítuto Superior Técnico, Universidade de Lisboa
Av. Rovisco Pais, 1049-001 Lisboa, Portugal
Paweł KULA
Silesian University of Technology, Faculty of Transport
Krasinskiego 8 Street, 40-019 Katowice, Poland
Şirin BALIK
Yıldız Teknik Üniversitesi
Yıldız Mh., Istanbul, Turkey
Oana-Alexandra MISTODIE
Universitatea Politehnica din Bucuresti
Splaiul Independenței 313, Bucharest, Romania
**Corresponding author*. E-mail: joao.s.ribeiro@tecnico.ulisboa.pt

DESIGN OF INTEGRATED AND CO-ORDINATED MULTIMODAL TRANSPORT SYSTEMS – NORTH SEA – MEDITERRANEAN CORRIDOR

Summary. The paper discusses the North Sea – Mediterranean corridor, part of the Trans-European transport network. A brief discussion on the aspects of multimodality and the possible modes of transport involved in transporting inland freight is presented followed by an introduction to main IT systems that can be implemented to increase the efficiency of freight transport. Presented also is a description on the envisaged investments in freight corridors in Europe. An assessment of information flows is also offered. The study concludes that the concept of a freight corridor should be extended to a network in order for more global benefits to be experienced.

PROJEKT ZINTEGROWANEGO I KOORDYNOWANEGO MULTIMODALNEGO SYSTEMU TRANSPORTOWEGO – KORYTARZ MORZE PÓŁNOCNE – MORZE ŚRÓDZIEMNE

Streszczenie. Artykuł omawia część transeuropejskiej sieci transportowej jakim jest Korytarz Morze Północne - Morze Śródziemnomorskie. Jest to krótka dyskusja na temat aspektów multimodalności i możliwych środków transportu zaangażowanych w przewóz śródlądowy, a następnie wprowadzenie do głównych systemów informatycznych, które mogą być wdrożone w celu zwiększenia wydajności transportu towarowego. Artykuł przedstawia również informacje o planowanych inwestycjach w korytarzach transportu towarowego w Europie. Badanie potwierdza, że należy rozwijać koncepcję sieci korytarzy towarowych w celu doświadczenia większych korzyści.

1. INTRODUCTION

The invention of the shipping container almost sixty years ago revolutionized the global trade market. Items used to be loaded, shipped and unloaded separately not allowing the existence of reduced handling costs. Then in the sixties came the standardisation which allowed stacking containers efficiently and lead to the globalization phenomenon. Nowadays, integration between different modes of transport with the utilization of standard 20-foot and 40-foot is more and more useful giving the agents the chance to be more environment-friendly. Standard container sizes are now still increasing towards a better optimisation of space/vehicle use for carrying goods.

The concept of TEN-T corridors along with the European Commission goals of improving the modal shift from road to railways and inland waterways may have opened a new path for multimodality in inland freight in Europe. For that reason, it is important to assess the impact of those routes in order to understand their real utility and to understand if the investments made have reason to be.

2. METHODOLOGY

The following steps were applied on the elaboration of the present paper: 1) brief research on multimodal transport regarding the main issues about multimodality for each transport mode involved on the European inland freight transport; 2) literature research about the IT systems that can be applied to improve the integration and co-ordination of freight transport systems; 3) definition of the structure of the North Sea – Mediterranean corridor; 4) statistical data research for analysis of main flows between NUTS 2 regions of the urban nodes influenced by the corridor which lead to study only railway related flows due to the absence of valid data for other means of transport.

3. MULTIMODAL TRANSPORT

3.1. Definitions

Practitioners and those embedded within the transport industry have often been using casually one single transport mode. However, since 2001 there is an official European definition of both terms, separating multimodal transport as being the *"carriage of goods by two or more modes of transport"* [1] and intermodal transport as the *"movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes"* [1]. Nevertheless, both terms are often ambivalent words and usually are misplaced when talking about multimodality or intermodality.

In the present paper the term *multimodality* is used for goods moving from one origin to a destination by different modes, which includes intermodality situations such as the utilization of containers for accommodating goods during travel, from end to end.

3.2. European Union's role

One of the main objectives of the European Commission regarding transport systems is related with the increase of efficiency and overall decrease of emissions. For that matter, the evolution towards more resource-efficient vehicles and cleaner fuels is not enough to meet the expected results. *"They need to be accompanied by the consolidation of large volumes for transfer over long distances. (...) for freight, multimodal solutions relying on waterborne and rail modes for long hauls"* [2].

In order to optimise the performance of multimodal logistic chains, the European Commission defined that it is expected that by 2030, 30% of road freight over 300 km shifts to rail or waterways and more than 50% by 2050. For achieving these goals, it is stated that all core seaports will have to be well served by rail freight and inland waterways.

3.3. Integration and co-ordination in logistics

The transport of goods between two specific locations using a multimodal option allows the minimization of travel costs through the selection of the optimal methods of shipment by the freight forwarder. However, inter-regional and international routes are complex chains with multiple issues that are not yet solved (legal/regulatory, institutional, contractual, informational, physical and economic barriers), therefore, contingent to the followed procedures by the freight forwarder, multiple routes are likely to obtain, each one of them with different possible performances.

3.3.1. Description

In logistics processes, co-ordination often refers to materials and information flows. Christopher (1992) states that one of the principles underlying the concept of integrated logistics is to plan and co-ordinate the materials and information flows that extend from the market place, through the firm and its operations and beyond that to suppliers. Hewitt (1994) maintains that supply network co-ordination relates to planning, monitoring and aligning intra and inter-organisational logistics processes, because such processes can be considered as the vehicle of materials, information and financial flows across the supply network. According to Slack (1991) and Slack et al. (2001), not only materials, components and information circulate in the supply network but also services, ideas and even people.

Integration as a mechanism to support business processes across a supply network is closely related with the effort to overcome intra and inter-organisational boundaries. Integration can support business at these two different levels:

"*1. Intra-company integration, aiming to overcome the functional silos boundaries, and relating to activities to manage and re-design the business processes across the individual members of the supply network (e.g. functional integration, rationalisation of internal processes, integration of internal information systems);*

2. Inter-companies integration, aiming to overcome the individual company boundaries, and relating both to an initial extent of integration, or ''inter-companies integration'', and to an advanced extent of integration, or ''overall supply network integration'' [3].

Moreover, authors generally recognise intra-company integration as a pre-requisite for inter-companies integration.

4. TRANSPORT MODES

Considering 2012 as the reference year, the European road network had a share of three quarters regarding modal split of freight transport (see Fig. 1) for inland freight transport. However, recent years show that in terms of relative growth there has been a change on the European freight transport scenario. Road utilization growth has stabilized and it is slowly decreasing since 2009. On the opposite way there has been a significant increase on the utilization of other means of transport, in contrast with the first decade of the present millennium (see Fig. 2).

Customers' main interest on a multimodal transport network is the ability to find the best way of combining transport performance (time) and cost. Multimodal transport usually combines two modes of transport but it can even combine more transport modes such as ship-train-truck for door-to-door deliveries. The most important factors on the determination of the modal choice can be identified as being the volume to weight ratio, the value to weight ratio, the products characteristics and cargo priority.

A brief review about five transport modes that can be involved in multimodal chains is presented on the next section.

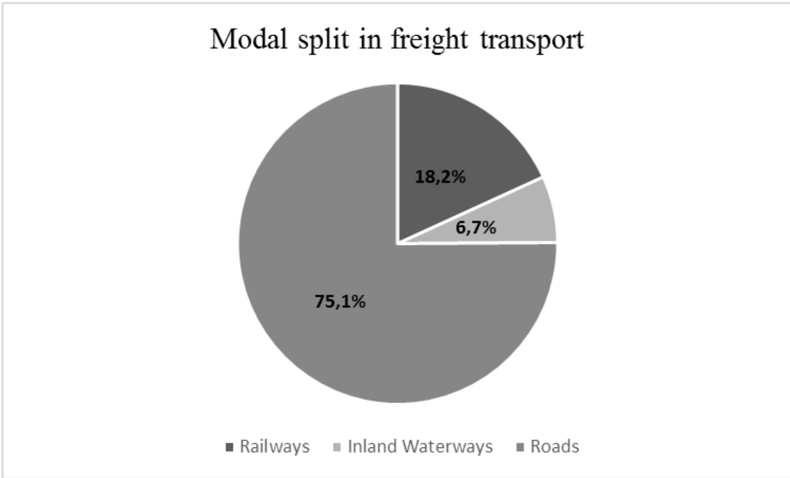

Fig. 1. Modal split of freight transport considering only roads, railway and inland waterways in EU-27 in % of total inland freight tonne-km

Rys. 1. Podział transportu towarowego, uwzględniając tylko drogi, kolej oraz wody śródlądowe w obszarze UE-27, ze względu na liczbę wykonanych tonokilometrów

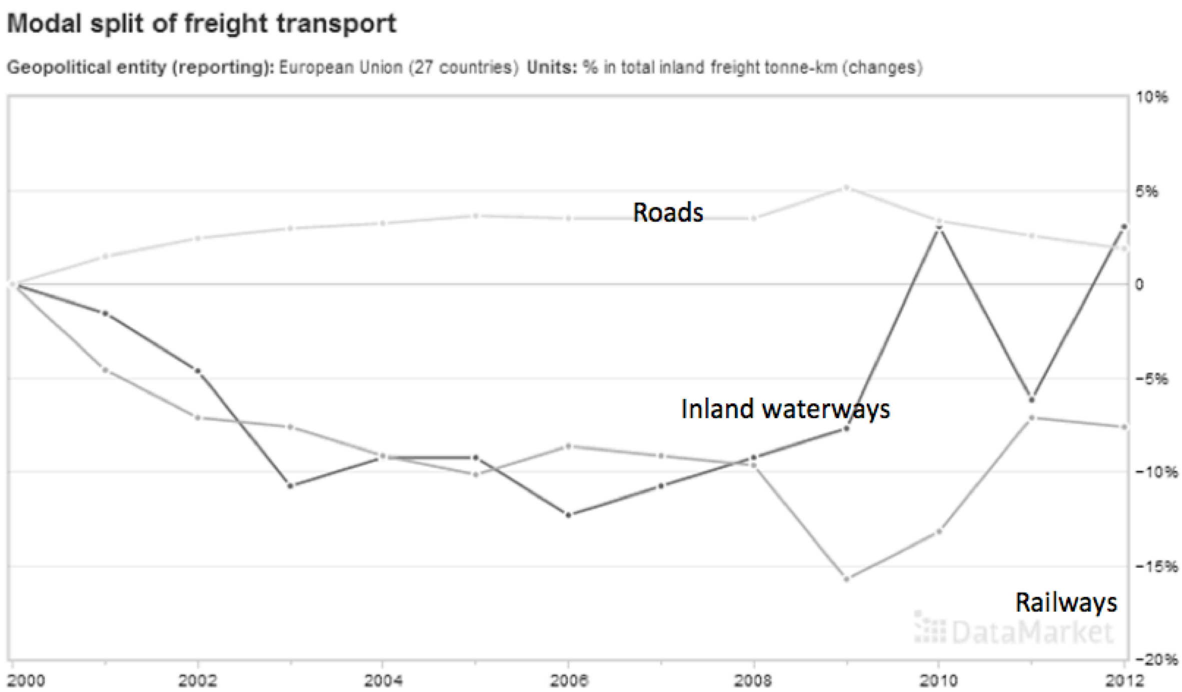

Fig. 2. Relative temporal evolution of freight transport market split considering roads, railway and inland water ways

Rys. 2. Zmiany w popycie na przewozy towarowe dla poszczególnych środków transportu w ostatnich latach

4.1. Maritime transport

Maritime transport has almost 37% of share of the total freight transport in the European Union. Notice that total volume includes not only containers but also huge volumes of bulk, mainly oil, which contributes extensively to the market share. Most of the inter-continental cargo is brought by ship and those vessels stop at several stops making their distribution in different countries. Short sea shipping which is the maritime transport without crossing any ocean has still little market share being mostly used close to Rotterdam and Scandinavia.

It is a slow mode of transport, but per unit of cargo it comes out as cheap and safety transport system. Unfortunately, emissions of ships are huge, but if we calculate emission per one container, emission is not very big.

4.1.1. Technical issues – shipping the cargo

Depending on the type and characteristics of the cargo to transport from one place to another, several types of vessels may be used: container ships, LNG carriers, tanker ships, bulk ships and roll-on/roll-off ships are some examples.

Multimodal transport is mostly based on ISO containers. It is the most efficient method in transport typical goods as it allows stacking, easy equipment manoeuvres and fast transhipment between transport modes. Container vessels were developed to carry this item and have a specific layout to allow the optimization of space utilization, similar to a warehouse divided into cells designed to hold the standardized containers. For moving cargo with specific requirements, special containers were also developed such as reefers, tanks, flat racks and other types of containers. Nevertheless, the containers still have the same ISO characteristics: volume and frame, which allow transporting containers on ships, barges, rails or trucks. The bigger container vessels have around 400 meters length and capacity 18 270 TEU (1 TEU = 20 feet container) and are usually used for inter-continental shipping.

In terminal operations, equipment such as cranes and reach stackers are used for handling the cargo, to load and unload ships from/for trucks and trains.

When transporting containers by ship, train or truck, the container is locked from moving using a twistlock system. It allows to protect the container on a simple, fast and safe way. It is installed on the trailer frame or truck chassis, on the frame of rail wagons or on the deck of vessels. ISO containers are adapted to use twistlock, allowing easier handling operations and safety during transport.

4.2. Road transport

Road transport in Europe is the most popular mode of transport in Europe. Relying on European Commission's statistic, almost 75% of total cargo is transported by trucks, when considering only inland freight transport by rail, road and inland waterways (see Fig. 1). The European standard of truck's dimensions is 40 tons weight, 2.5 meters wide and 4.0 meters high (except in UK) and 16.5 meters length (tractor with semi-trailer) or 18.75 meters (rigid truck with trailer) but in Scandinavian countries, trucks could have more length and weight – 25.25 meters long and 60 tons.

Scandinavian experiences show that bigger trucks are more efficient and ecological. The safety is the same like the standard trucks. In recent years, other countries (e.g. Netherlands, Belgium or Germany) are testing this type of trucks.

4.2.1. Operational issues – shipping the cargo

Swap bodies are standardized containers used in rail and road transport, especially in Europe and UK. The swap body is similar to the ISO container but it needs special chassis, semi-trailer or trailer. The reason is that the trucks' frames have standardized size and clamping systems which purpose is to improve the efficiency of transport. The production of swap bodies is more expensive than the production of ISO containers. Although, the swap body weighs less than the ISO container which allows saving money during transport of cargos, due to the reduced ratio between weight/size which allows loading more units, becoming more efficient.

4.2.2. Operational issues – modal interaction

There are different ways of having multimodal transport by using trucks: several options are available, such as using rail wagons or ferryboats to transport trucks with trailers or just trailers. Ferryboat is a popular form of transport between France and UK or Scandinavia and the rest of Europe. Other example of this kind of multimodality is the popularity in Austria of the utilization of trucks on railway wagons due to the countries' restrictive emission and noise standards.

4.3. Rail transport

The Trans-European Railway network consists of both high-speed and conventional rail lines and their related infrastructures and facilities. In order to optimise the performance of multimodal logistic chains, the European Commission defined that it is expected that by 2030, 30% of road freight over 300 km shifts to rail or waterways and more than 50% by 2050. For achieving these goals, it is stated that all core seaports will have to be well served by rail freight and inland waterways. As containerisation of freight is continuously growing, road congestion is increasing and oil prices keep getting higher, these transport modes will have a greater importance in the future of the freight trade on the European continent.

4.3.1. Technical issues – terminal location options

Authors have proposed several possibilities about the optimal location of rail terminals. One of the most essential in order to have a functional multi-modal chain is the existence of a rail terminal located near seaports, where most of the goods arrive and railways can provide connections between port terminals and the inland multimodal chain.

According to Reis et. al, several typologies can be found: on-dock rail terminal (where containers are transferred directly from the storage area into railcars with the terminal's own equipment), near-dock terminals (where customs clearance is made on the near-dock rail terminal after clearing the terminal's gate, leading to more available space in docking areas) and satellite terminals (which can be classified as a form of inland port due to its load centre and trans-modal terminal).

4.3.2. Operational issues – modal interaction

The existence of a Trans-European network requires different kind of terminals other than maritime-rail terminals. Logistics platforms where bundling operations can be made between different modal options are fundamental for the efficiency of multimodality. These locations have to provide storage areas, logistic centres, refer facilities and special warehousing conditions. Traditionally, the transfer of cargo between trains is made through shunting operations but intermediate transhipment can take place in rail-rail exchange which have similar infrastructure to road-rail and road-barge terminals. Notice that exchange operations will instantly increase total time and costs of transports and therefore these operations have to be efficient and fast, [5].

4.3.3. Operational issues – accommodation of goods

Modern railway wagons are now suited for most of traffic requirements. Conventional wagons are designed for specific cargo types such as solid and liquid bulk or palletised goods. Inter-modal wagons are designed to transport items such as containers or swap bodies, providing better conditions for transferring road trailers into wagons or vice-versa with only standard equipment for load/unload operations. These kinds of wagons help to keep train services on time improving the network efficiency reducing delays.

According to The Freight Best Practice, fixed costs have higher levels than variable costs *"which tends to mean that the additional cost of going an extra mile by rail or water is much lower once the costs of loading on and off the train or barge has been paid."*

4.4. Inland waterways transport

Europe has around 1 500 inland ports. More than half of those are located in the main inland waterways TEN-T corridors. The Trans-European Inland Waterway network consists on the involvement of the available 30 000 km of navigable rivers, canals and branches on a core freight network. Mostly of the referred possible routs links the Netherlands, Belgium, Luxembourg, France, Germany and Austria and there is also good inland water connection with the Eastern Europe through the Danube.

Inland waterway transport offers a very energy efficient, reliable and safe mode of transport. It has a growth potential not yet fully explored and according to the European Commission's Transport White Paper, inland waterways, by linking the European seas, will have an increasing role in the freight sector. However, there has been a problem of underinvestment in barges across Europe and a big share of the existing barges are coming close to the end of the life cycle. A main issue can be pointed nowadays and for the future: who's going to invest for barges in the future if the goal is increasing its utilisation?

4.4.1. Technical issues – terminal location options

Inland waterway infrastructure is still poorly inter-connected and the lack of integration and fragmentation of its infrastructure and, for instance, the known fragmentation of its labour force are often considered as obstacles to its growth. On the other hand, it may be affected by extreme weather events such has drought periods, floods or ice occurrence, compromising scheduled port or barge movement operations.

Inland rivers ports are located on the waterfront of rivers for loading and unloading barges. There are three types of terminals: general purpose terminals (designed to handle various types of goods – bulk, general cargo or containers); special purpose terminals (specialized for handling a specific type of commodity); industrial terminals (not related to the multimodal system, they usually serve a specific industrial facility.

4.4.2. Operational issues – modal interaction

A river port has to provide conditions for exchanging goods between different transport modes. Therefore it is needed to ensure that ports have the necessary equipment, terminals and storage areas required for a quick exchange of goods between transport modes. In the scope of the White Paper, in order to increase the efforts to reach sustainable mobility, improvement of the service portfolio of ports has to be made regarding a higher level of traffic management with logistics operations inducing an improvement on quality of service for door-to-door service. The appearance of containerized transport of goods increased the importance of inland waterways in the connection between sea ports and their hinterland due to its advantage of calling directly in the waterside of the sea port requiring only gantry cranes to make the transhipment of cargo. However, deep-sea vessels have priority on crane operations and so, when a barge needs to unload part of its containers it usually has to wait for uncertain time.

The development of hinterland networks through consolidated rail and road networks, with the appropriate truck traffic management and the adequate frequencies of train departures, with fixed timetables are fundamental to ensure a service suited to the hinterland market needs [6].

4.4.3. Operational issues – accommodation of goods

Goods such as liquid or dry bulk are typically carried as so are containers and palletized materials.

Inland waterways have limitations due to restrictive natural depth and width. However, several rivers allow the usage of until up 750 Tonne barges where economies of scale can be achieved (usually barges carry some 140 to 400 TEU). Usually the ship has to unload containers along several terminals up the river and so, a good cargo management is required for efficiency of processes. Crossings below low bridges may also be critical for the vessel's total height, not allowing sometimes the barges to be fully loaded. Notice that the rivers natural depth on low tide may also constraint the total cargo on the barge.

4.5. Air transport

The use of air transport for freight transport is relatively rare mostly due to the expensive costs related to it. Although, in case of need of a fast, safe and reliable transport for moving urgent, perishable or valuable cargo, air freight transport is the most suitable.

4.5.1. Technical issues – transport to and from the terminal

Cargo is usually provided to the airport by truck operators, due to the usual inexistence of direct connections with railway inside the airport.

4.5.2. Operational issues – shipping the cargo

Airplanes have a huge constraint about the carried weight. Therefore regular ISO containers used in other transport modes cannot carried due to those weight constraints and also their shape which don't fit in the round cross-section of the aircrafts.

Sometimes air freight operators do not ship the cargo by air but instead, they send the merchandise by road. This way of operating raises questions about the split of modal share: is the air cargo considered as transported by an aircraft or by truck?

5. INFORMATION TECHNOLOGY SYSTEMS

5.1. Using IT for co-ordinating and integrating the transportation process

There are three flows in the logistics function (see Fig. 3): the material (physical) flow, the information (documentary) flow and the financial flow.

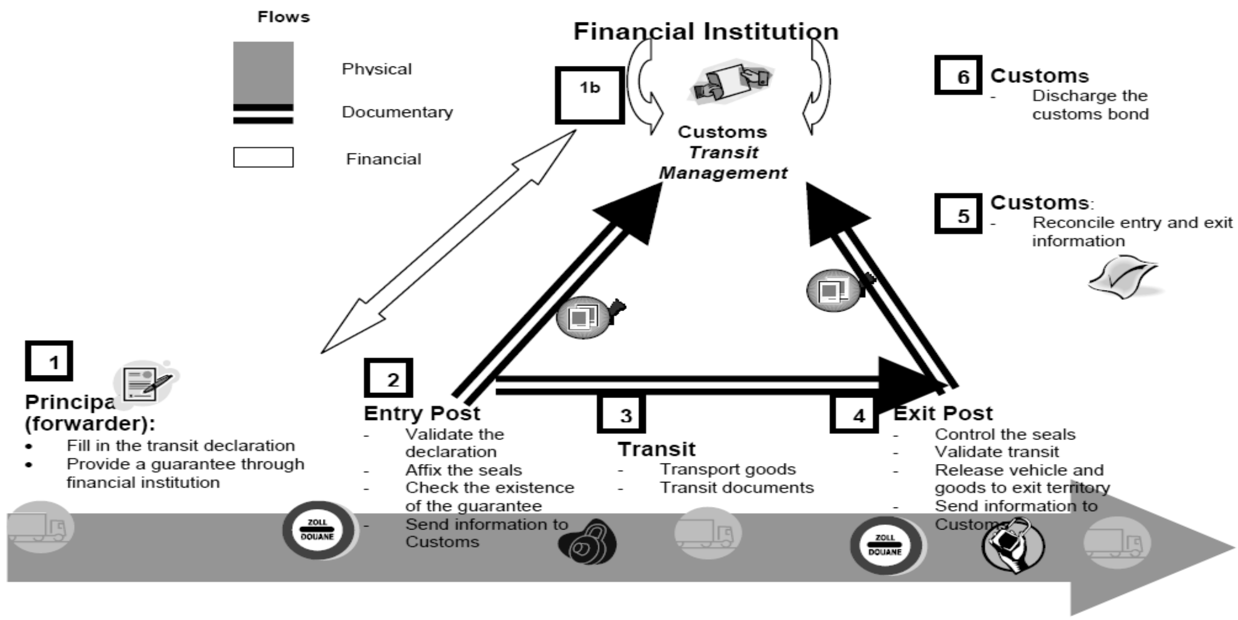

Fig. 3. Information flows
Rys. 3. Przepływ informacji

IT improves the current logistics functions of the organizations, and it changes the structure of logistics operations (e.g., by eliminating distributors and making contact with customers directly by using IT solutions). These systems use information, forecasting and communication between supply chain members to support decision makers, control and monitor supply chain operations.

The information that should be used in communication is too complex. Therefore, mathematical and statistical models are developed for overcoming some of the most difficult planning and control problems.

5.2. IT system characteristics

The characteristics of Logistic Information Systems (LIS) are the following:

- *Availability:* the availability of information is pre-requisite in responding to customers, improving management decisions, co-ordination and integration.
- *Accuracy:* to reduce inventory requirements, information used should have enough accuracy. That makes coordination and integration easier.
- *Timelines:* timeline means the delay between the starting of an event and the recognition of that event in the information system. Timely information is helpful for coordination and it increases decision accuracy, also reduces inventory requirements. In the case of railway freight transport, there is still a big issue regarding independent access to timetables to be aware of disruption responses in the freight transport.
- *Exception-Based LISs:* LISs should be designed as sensitive for exceptions such as very large orders, products with little inventory, delayed shipment and declining operating productivity.
- *Flexibility:* LIS must be flexible enough to meet needs of customers and system users.
- *Appropriate Format:* Logistics reports and screens must contain the right information in the right structure and sequence.

5.3. Information and communication technology

Thanks to the development of technologies, transferring information is now more efficient, secure and lower-cost today than when comparing to manual systems. Furthermore, they help improving customer services, and get lower response times. IT applications in logistics can be listed as follows:

- *Data collection:* optical scanning, electronic-pen notepads, voice recognition and robotics
- *Identification:* bar codes, radio frequency (RF) tags and antennas, smart cards, magnetic strips, and vision systems
- *Positional systems:* (GPS-MPSGIS-Navigator) for lorry/truck tracking
- *Communication networks and data exchange:* (EDI-XML-Internet-Satellite-LANWAN-EPOS)
- *Data storage:* data marts and data warehouses
- *Software:* DSSs, artificial intelligence, general software and LIS modules

For instance, in vehicle-tracking systems, a vehicle's position can be monitored using GPS (see Fig. 4). GPS technology provides better vehicle, load and driver security and timely deliveries with lower costs through reduced waiting and standing time because exact vehicle arrival times are available.

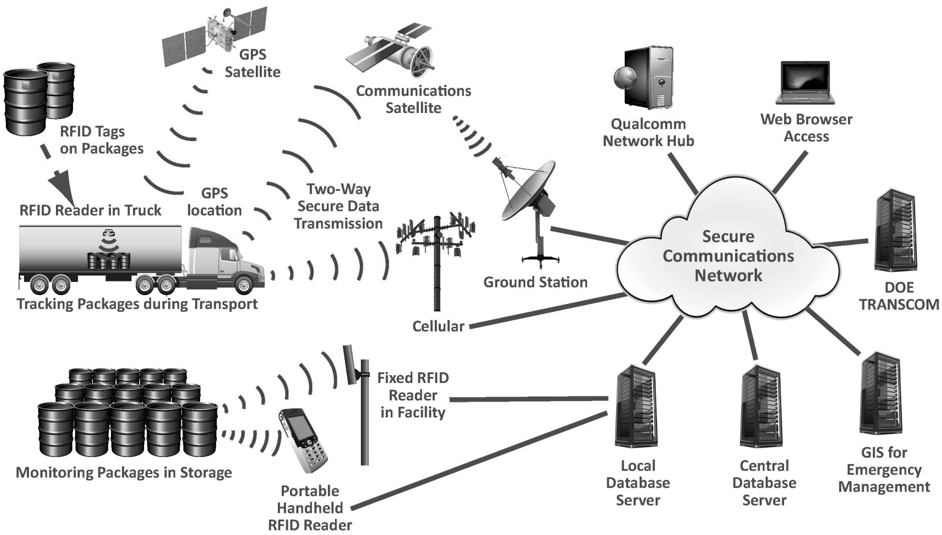

Fig. 4. Information and communication technologies for transportation
Rys. 4. Technologie informacyjne oraz komunikacyjne w transporcie

5.4. Importance of co-ordination and integration with IT systems

For traders at the origin or the destination of the supply chain, what matters most is the quality and reliability of logistics services, measured by the predictability of the clearance process and timely delivery of shipments to destination.

Since information technology has not been much developed, it was much more difficult to coordinate and integrate transport operations and thus it was also difficult to prevent accidents. So, European Research Programme launched ERTMS. ERTMS is a management system that increases safety in rail transport by ensuring continuous monitoring of rail transport operations.

The ETCS is a computer system that compares the speed of train and allowed maximum speed on track and slows down the train if it has exceeded the maximum speed.

5.4.1. The three components of total transportation costs

- *Transportation costs:* fees paid for actual transit transportation services to truckers or rail operators;
- *Other logistics costs:* transit overheads: fees, procedures, facilitation payments; fixed costs of shipments;
- *Delay hedging costs:* in-transit moving inventory costs; induced costs to hedge unreliability plus inventory and warehousing costs or to shift to a faster, more expensive mode of transportation.

As it's shown in Table 1, any possible delay means extra cost and should be minimized. The most important source of delay is initiating transit in ports, which typically takes as much time as final clearance. The second source is final clearance at destination. Minimization can be done by coordinating and integrating every mode of multimodal transport logistics using information technology systems.

Table 1

Contribution of selected supply chain links to cost factors

	Direct costs	**Overheads**	**Delay**
Port handling	*High to very high*	-	Variable
Initiation of transit procedure	Average to high	*High*	*High to very high*
Rail transport	Average to high	-	*Higher than road transport*
Multimodal facilities	Moderate	Moderate	Moderate to high
Regulated road transport	Average to high	Average to high	Moderate
Liberalized road transport	Average to high	Low	Moderate
Transit convoys	Moderate	Moderate	Moderate
Checkpoints	-	*High*	Moderate to high
Border crossing	Low	Moderate	Moderate to high
Final clearance	Low	*High*	Moderate

Using IT technologies in logistics is very important for both managers and researchers. To meet their demand, "Eyefortransport Institute" conducted a "Technology in Transportation and Logistics" survey in Chicago, USA. The analysis of the statistical results conducted by the answers given to two important questions asked in the survey, (1) *"To what degree was a company working with a selection of technologies?"* and (2) *"What degree were a company's selection of technology capabilities and services customer driven?"* allowed to conclude that a significant part of these companies are already work with developing information technologies or are planning to work with it in a near future. Results also showed that companies make their choices for information technologies to use, considering their customers' needs. Today, using IT is an obvious requirement both customers and companies.

6. CASE STUDY

6.1. Trans-European Transport Networks (TEN-T)

The Trans-European Transport Networks (TEN-T) are a planned set of road, rail, air and water transport networks in Europe connecting the continent between East and West, North and South.

Transport infrastructure, as well as energy and telecommunication networks, was necessary for the integration of the European market, with freedom of movement for goods, persons and services, including interconnection, interoperability and access between national networks. It also has an important role on achieving the European Commission's goal of accomplishing an efficient multimodal transport across Europe.

6.2. Core network corridors

According to the European Commission, the TEN-T core network corridors work as a new *”instrument for the implementation of the trans-European transport network – is a strong means of unlocking cooperation potential of the Member States, regional and local authorities, infrastructure managers, transport operators, transport users and other stakeholders to achieve a better development and management of infrastructure”*. Transport networks are an important part of this concept. According to the EC sources, the European states dispose of *”5 000 000 km of paved roads, out of which 61 600 km are motorways, 215 400 km of rail lines, out of which 107 400 km electrified, and 41 000 km of navigable inland waterways.”*

”Core network corridors” were introduced to facilitate the coordinated implementation of the core network. They bring together public and private resources and concentrate EU support from the CEF (Connecting Europe Facility initiative), particularly to remove bottlenecks, build missing cross-border connections and promote modal integration and interoperability. In parallel, it also aims at integrating rail freight corridors in the multi-modal TEN-T corridors, promoting clean fuel and advancing telematics applications for an efficient infrastructure use as well other innovative transport solutions.

There are currently nine core networks corridors identified: the Scandinavian-Mediterranean corridor, the North Sea-Baltic corridor, the North Sea-Mediterranean corridor, Baltic-Adriatic corridor, Orient/East-Mediterranean corridor, Rhine-Alpine corridor, Atlantic corridor, Rhine-Danube corridor and the Mediterranean corridor. This paper will analyse the North Sea-Mediterranean corridor as a great percentage of the network is already built.

6.3. The North Sea – Mediterranean Corridor

The North Sea-Mediterranean corridor goes from Ireland and the north of the United Kingdom linking towards south The Netherlands, Belgium and Luxembourg and through Eastern France until the Mediterranean Sea on the south. As the other European corridors, its goal is to improve the efficiency of the multimodal transport in Europe. On Fig. 5 it is shown a representative scheme on the corridor's layout. In colour scale the corridor is visible.

6.3.1. Main missing links

”The main missing links on the “continental part” are the inland waterways bottlenecks and missing links between Seine and Scheldt as well as between the Rhine and the Rhone with the Canal Seine-Escaut as the most well-known project under development.” (European Commission, 2010). About the railway connections in the continent, the cross-border rail connections between Brussels, Luxembourg and Lyon need to be improved to be able to compete with road transport. Several projects are yet to be accomplished in this corridor, mostly upgrades of existing railways, improvement on the inland waterway connections and development of multimodal platforms and interconnections between modes, which will be fundamental for the proper functioning of the corridor. Although, a good part of the railway network is already working and, as an example, in 11 December 2011 the first phase of the new eastern branch Dijon-Mulhouse (190 km) was opened and lead to cut travel times to 3 hours 40

minutes from Strasbourg to Lyon instead of 4 hours 40 minutes, according to the European Commission. The full high-speed line Rhine-Rhone will connect the high-speed network around Lyon to those of eastern France and with Switzerland and Germany.

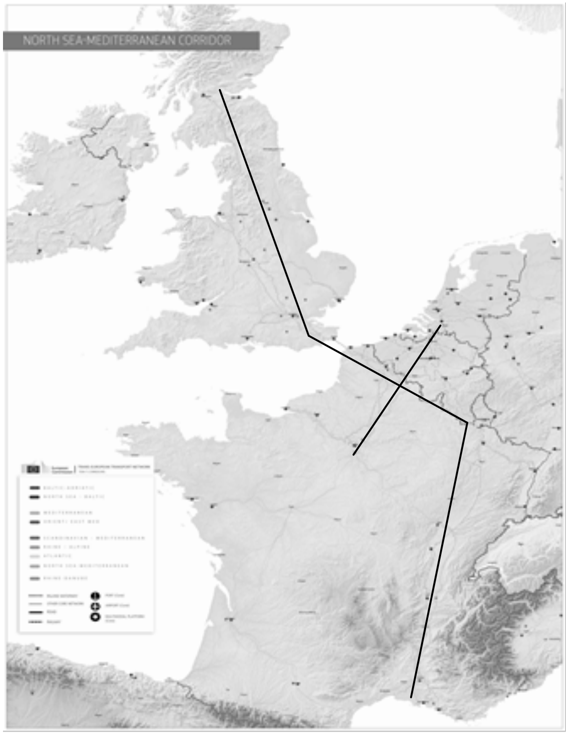

Fig. 5. Representative scheme of the corridor layout
Rys. 5. Schemat prezentujący układ korytarza

While the TEN-T concept focuses on infrastructure investments, the RNE-corridors address timetabling and capacity allocation issues; the core task of the ERTMS-corridors is the deployment of the European Train Control system and the promotion of interoperability.

6.3.2. Priority projects related to the corridor

Some of the funding provided for the TEN-T corridors are invested on few priority projects to establish the planned corridors. On the North Sea-Mediterranean are involved:

- *Priority projects 2 (France, Belgium, Germany, Netherlands, UK):* it is the high-speed railway network, which connect few big cities in Europe – London, Brussels, Köln, Paris and Amsterdam. It connects UK and mainland Europe under canal between Dover and Calais. Their offer is directed to passengers. It's very good alternative to air and road transport, because significantly saves time.
- *Priority projects 13 (UK, Ireland):* PP13 is a road network between Britain and Ireland. It saves journey times, reduces the amount of accidents and environmental costs. This network includes roads like motorways, expressway, single and dual carriageway. The network connects ports in east cost of Britain with ports in North Wales, North West England (Liverpool), Scotland and Ireland.
- *Priority Project 14 (UK):* the west coast main line (WCML) is the most important railway network in UK and connects the biggest cities in UK – London, Cumbria, Manchester, Liverpool and Scotland . It can save time of journey for passengers and freight also.
- *Priority Project 26 (UK):* includes roads and rails. Both run paralleled and connect the west and the east coasts. It also links Cork and Larne in Ireland. It allows the reducing of journey's time of passengers and freights. All sections should be done in 2020.

- *Priority Project 28 (Belgium, Luxembourg, France):* It has almost 400 km of high-speed rail network between 3 capitals of European Union – Brussels, Luxembourg, Strasbourg. It connects the North Sea and areas such as the South of France, Switzerland and Luxembourg.
- *Priority Project 30 (France, Belgium):* Inland waterway which connects France and Belgium. It also has influence on other countries like the Netherlands or peripheral countries. PP 30 should improve inland transport by large barges.

6.3.3. Assessment of existing infrastructure on main links

Table 2 accounts the current existing infrastructures along the main links of the corridor between urban nodes.

Table 2

Existing infrastructure along main links of the corridor

Link	Completed conventional railways	Completed high-speed railways	Completed core road network	Operating waterways	Airports	Ports	Rail-road terminals
Glasgow - Edinburgh	✓	✓	✓		2	2	
Glasgow, Edinburgh – Manchester		✓	✓		3	3	
Manchester – Birmingham		✓	✓		2		
Birmingham – London		✓	✓		6		
Cork – Dublin	✓		✓		2	2	
Dublin – Belfast	✓		✓				
London – Lille	✓	✓	✓		6	6	
Lille – Brussels			✓		2	4	
Lille – Antwerp	✓		✓	✓		4	
Antwerp – Rotterdam	✓		✓	✓		4	
Rotterdam – Amsterdam	✓		✓	✓	2	2	
Brussels – Luxembourg	✓		✓		2	3	1
Luxembourg – Paris	✓		✓		3	2	1
Luxembourg – Dijon	✓		✓				2
Luxembourg – Strasbourg	✓		✓			2	
Strasbourg – Dijon	✓		✓	✓			
Dijon – Lyon	✓		✓				
Lyon – Marseille	✓		✓	✓	2	2	

6.3.4. Distribution along NUTS 2 regions in the corridor

To assess the effectiveness of the corridor, statistical data is fundamental. Unfortunately the lack of statistical information is one of the major issues about freight transport systems across Europe. The huge competitiveness on the market and the absence of integration of the IT systems on the freight transport does not help the collection of accurate data. When looking in freight transport from region to region the problem gets even deeper: data for NUTS 2 regions are only available for rail freight (for road and inland waterway there is only data about country to country transportation) and data about origin-destination is not available for most of the countries and when it exists (United Kingdom and Netherlands) is only related to the national market. Only France provides the loading and the unloading regions at national and international level. On Table 4 it is presented the percentage of total unloaded cargo with origin in each France NUTS 2 region belonging to the North Sea – Mediterranean corridor.

6.3.5. Distribution with origin in France

The region of Nord-Pas-de-Calais is the French region that contributes the most to the rail freight with origin on urban nodes along the corridor. It is probably related to its proximity to the two biggest ports in Europe, the Port of Rotterdam and the Port of Antwerp, as well its proximity to the English Channel. This region also has two operating rail-road terminals which may also induce the intermodality between trucks coming from the closest ports and trains departing to South.

When looking at the total unloading by region, probably due to its proximity to the borders of several Central Europe countries (Belgium, Germany, Luxembourg and also Switzerland) and also the easy access with other TEN-T corridors such as the Atlantic corridor, the Lorraine region is the one with the biggest share.

Interesting to notice that only a really small percentage of the total loaded cargo in France goes to foreign countries. The fact that the available data is from 2010 and the existence of several bottlenecks on the France/Belgium border before the implementation of the project Rail Freight Corridor 2, in 2013 can be a possible explanation for this low percentage, influencing the increase on multimodality by rail-road exchanges for the freight transport between France and Belgium (and as well the Netherlands) (see Table 3).

Notice that the total percentage by each loading region is related to the total cargo loaded with destinations along the corridor. Other cities/regions are not considered.

- *Lille/Dunkerque (Nord-Pas-de-Calais):* of all the considered French regions, Nord-Pas-de-Calais is the one which contributes with the highest volume of the considered loaded cargo (31.4%), as it is the region with more connections to other surrounding regions and also closer to other countries, with important sea ports in the area. Almost 50% of the loaded cargo has the region of Metz as destination. Notice that this region by being close to the German border has close connections to other TEN-T corridors like the Rhine – Alpine, the Atlantic and the Rhine-Danube corridors.
- *Metz (Lorraine):* more than 50% of the total loaded cargo in this region is unloaded from the train within the same region. The connection to Lille is the most used one (17%) and Paris follows with 12%. However, the Atlantic corridor makes the connection between Metz and Paris thus it is more often used to carry freight between the two regions. Only 3% of the loaded cargo in Alsace has Belgium as destination (Antwerp). Only around 10% of the commodities from the Lorraine region go to the South of France and therefore the corridor doesn't have much influence on distribution from this region.
- *Paris (Île de France):* around 40% of the loaded rail freight cargo in the region of Paris goes to the region of Marseille. The North Sea – Mediterranean corridor from Paris goes firstly to Northwest to Lille. Looking at the core railway connections for freight, a conventional track links Paris to Dijon which is other urban node belonging to the TEN-T corridor. Therefore, it is most likely that more than 50% of the total loaded cargo from Paris that goes to the South of France uses only a segment of the corridor, between Dijon, Lyon and Marseille.
- *Strasbourg (Alsace):* around 20% of the commodities go to the region of Lyon and the same to the region of Paris. After the two biggest French cities, Antwerp is the major destination of the loaded cargo in the region of Alsace.
- *Dijon (Bourgogne):* the South region of Marseille is the main destination of the loaded cargo in this region (29%). The peripheral regions like the region itself, Alsace and Lorraine follow Marseille has main destinations.
- *Lyon (Rhône-Alpes):* almost half of the total loaded cargo in this region is also unloaded in the same region. The corridor is used for the second major destination of this region's cargo, the region of Marseille.
- *Marseille (Provence-Alpes-Côte d'Azur):* the corridor is probably used for the regional distribution at Provence-Alpes-Côte d'Azur, as around 35% of the loaded cargo stays within the region. The region also provides commodities to the regions of Lyon (20%) and Dijon (13%). Paris, as the third major destination from this region, as a share of 17% of all the distributed cargo when only considering destinations along the corridor. Once again, this connection is most likely to be provided by other conventional freight tracks than the North Sea – Mediterranean corridor itself.

7. CONCLUSIONS

According to the European Commission, multimodality on freight transport is the answer to reduce overall freight transport emissions and improve its efficiency. Also, other main goal reported on the White Paper of Transports from 2011 is to move 50% of the road freight above distances of 300 km to rail. It appears however that many barriers for the integration of the European transport systems still exist and therefore, some priority projects were defined (such as the Trans-European Transport Networks and Rail Freight Networks) to improve the interconnection, interoperability and access between different national networks.

TEN-T corridors are not yet fully implemented but the evolution of modal split in the inland freight transport has been changing on the recent years. Although, there is still a big lack of useful information to evaluate the main flows in Europe due to the competitiveness in the sector and absence of legislation regarding the collection of data related to Origin-Destination pairs and multimodality. The implementation of common IT systems to integrate and co-ordinate different transport systems and operators may be a step forward to achieve the goal of having a fully connected network for freight transport providing useful services for all agents in the process.

There is still a lot of work to be done to promote and integrate multimodal transport and fundamental statistical data sets are not yet available due to the absence of regulation at European level to ensure that all involved entities provide the necessary information. IT systems can have a major role in the improvement of the collection of data.

This research work suggested that there is a major difficulty regarding the collection of data for analysing for instance the impact of the North Sea – Mediterranean corridor on the European freight transport scenario. The information available on Eurostat is scarce and is not 100% accurate when found. Some assumptions were made through the analysis such as the utilisation of data from 2010, before the investment on the priority projects of the corridor which are supposed to decrease the main existing bottlenecks on the network. These bottlenecks may even not exist anymore and therefore the impact of the corridor may have changed the scenario close to the Eastern French border and changed the global rail freight scenario too.

Nevertheless the concept of a "corridor" should be extended to a core network with priority investments to improve travelling times and reduce main bottleneck issues on the network. With a strong transportation network, agents can always find their own "corridors" that suit them best and hence experience a better service.

Table 3

Total loading and unloading by French region
(Source: Adapted from Eurostat, 2010)

	Urban Nodes	NUTS 2 Region	% total loading	% total unloading
BE	Bruxelles	Brussels-Capital Region		0,10%
	Antwerp	Antwerp		2,57%
	Ghent	East Flanders		0,85%
	Bruges-Zeebrugges	West Flanders		0,01%
FR	Paris	Île de France	8,38%	13,44%
	Dijon	Bourgogne	4,41%	5,46%
	Lille/Dunkerque	Nord - Pas-de-Calais	**31,38%**	15,90%
	Metz	Lorraine	19,07%	**26,91%**
	Strasbourg	Alsace	5,38%	4,09%
	Lyon	Rhône-Alpes	13,30%	13,80%
	Marseille	Provence-Alpes-Côte d'Azur	18,09%	15,82%
LU	Luxembourg	Luxembourg		1,01%
NL	Amsterdam	North Holland		0,00%
	Rotterdam	South Holland		0,04%
		Total	100%	100%

Table 4

Percentage of loading and unloading by region

			Rail cargo loaded in:						
			Île de France	Bourgogne	Nord - Pas-de-Calais	Lorraine	Alsace	Rhône-Alpes	Provence-Alpes-Côte d'Azur
	Urban Nodes	NUTS 2 Region	Paris	Dijon	Lille/Dunkerque	Metz	Strasbourg	Lyon	Marseille
BE	Bruxelles	Brussels-Capital Region	No Data	0,00%	No Data	0,54%	0,00%	No Data	No Data
	Antwerp	Antwerp	2,82%	0,19%	3,00%	2,11%	11,67%	2,19%	0,35%
	Ghent	East Flanders	0,85%	0,36%	0,35%	0,27%	5,15%	0,36%	1,52%
	Bruges-Zeebrugges	West Flanders	0,05%	0,03%	0,01%	0,00%	No Data	0,02%	0,01%
FR	Paris	Île de France	12,08%	3,35%	15,00%	11,93%	21,60%	7,74%	17,20%
	Dijon	Bourgogne	2,26%	19,93%	1,68%	2,70%	4,77%	5,29%	13,23%
	Lille/Dunkerque	Nord - Pas-de-Calais	17,58%	8,05%	26,59%	16,48%	5,16%	9,63%	5,67%
	Metz	Lorraine	9,65%	11,03%	44,72%	53,03%	7,63%	3,02%	3,66%
	Strasbourg	Alsace	1,68%	17,64%	1,91%	5,20%	7,72%	4,22%	3,31%
	Lyon	Rhône-Alpes	8,53%	6,46%	2,80%	5,18%	23,64%	45,95%	19,64%
	Marseille	Provence-Alpes-Côte d'Azur	44,10%	28,97%	3,01%	2,44%	5,06%	20,83%	35,34%
LU	Luxembourg	Luxembourg	0,38%	3,94%	0,92%	0,07%	7,49%	0,71%	No Data
NL	Amsterdam	North Holland	No Data	No Data	No Data	0,02%	No Data	No Data	No Data
	Rotterdam	South Holland	0,00%	0,05%	0,01%	0,02%	0,12%	0,03%	0,09%
IE	Dublin	Southern and Eastern	No Data	No Data	No Data	No Data	No Data	No Data	No Data
	Cork	South-West Region	No Data	No Data	No Data	No Data	No Data	No Data	No Data
UK	Edinburgh	Eastern Scotland	No Data	No Data	No Data	No Data	No Data	No Data	No Data
	Glasgow	South Western Scotland	No Data	No Data	No Data	No Data	No Data	No Data	No Data
	Manchester	Greater Manchester	No Data	No Data	No Data	No Data	No Data	No Data	No Data
	Birmingham	West Midlands	No Data	No Data	No Data	No Data	No Data	No Data	No Data
	London	Inner / Outer London	No Data	No Data	No Data	No Data	No Data	No Data	No Data
	Liverpool	Merseyside	No Data	No Data	No Data	No Data	No Data	No Data	No Data
	Felixtowe	East Anglia	No Data	No Data	No Data	No Data	No Data	No Data	No Data
	Harwich	Essex	No Data	No Data	No Data	No Data	No Data	No Data	No Data

References

1. United Nations. *Terminology on combined transport*. Geneva (Switzerland): United Nations. 2001.
2. European Commission. *Roadmap to a Single European Transport Area – Towards a competitive and resource-efficient transport system*. 2011.
3. Romano, P. Co-ordination and integration mechanisms to manage logistics processes across supply networks. *Journal of Purchasing and Supply Management*. 2003. Vol. 9. No. 3. P. 119–134.
4. Reis, V. & Meir, J.F. & Pace, G. & Palacin, R. Rail and multi-modal transport. *Research in Transportation Economics*. 2013. Vol. 41. P. 17-30.
5. Macharis, C. & Bontekoning, Y.M. Opportunities for OR in intermodal freight transport research: a Review. *European Journal of Operational Research 153*. 2004. P. 400-416.
6. Bartošek, A. & Schönemann, R. *Bundling Networks for Intermodal Freight Flows to the European Hinterland*. Number 4. Volume VII. 2012. Available at: http://pernerscontacts. upce.cz/28_2012/Bartosek.pdf
7. Asadi, S. *Logistics System: Information and Communication Technology.* Logistics Operations and Management: Concepts and Models. Chapter 12. 2011. P. 221-245.
8. Arvis, J. & Raballand, G. & Marteau, J. *The Cost of Being Landlocked: Logistics Costs and Supply Chain Reliability.* World Bank Policy Research Working. 2007. P. 42-58.
9. Gittins, R. *How the invention of a box changed our world*. 2006. Available at: http://www.smh.com.au/news/business/how-the-invention-of-a-box-changed-our-world/2006/06/11/1149964409162.html%0A
10. Plompen, W. *Establishing Guidelines for Port Hinterland Intermodal Inland Waterway Transport Network Design.* MSc Thesis. TU Delft. 2014.
11. Department for Transport. *Freight Best Practice - Choosing and Developing a Multi-modal Transport Solution*. England. 2010. Available at: www.businesslink.gov.uk/freightbestpractice
12. *Decision and Information Sciences*. Available at: http://www.dis.anl.gov/projects/rfid_tech.html
13. *OMRON Develops a World-First Technology for Measuring the Distance Between RFID UHF-band Antenna and IC Tags*. Available at: http://www.omron.com/media/press/2007/09/p0910.html
14. *Logistics Viewpoints – Read&Think&Shear.* Available at: http://logisticsviewpoints.com /2009/11/20/dows-rfid-journey/
15. *The Core Network Corridors: North Sea – Mediterranean corridor*. Available at: http://ec.europa.eu/transport/themes/infrastructure/ten-t-guidelines/corridors/doc/northsea_mediterranean.pdf
16. *Infrastructure – TEN-T – Connecting Europe.* Available at: http://ec.europa.eu/transport/themes/ infrastructure/ten-t-guidelines/corridors/index_en.htm
17. European Parliamentary Research Service (2014). *Inland waterways in the EU.* Available at: http://www.europarl.europa.eu/RegData/bibliotheque/briefing/2014/130684/LDM_BRI(2014)130684_REV1_EN.pdf
18. European Commission. *Intermodal Freight Terminals – In search of efficiency to support intermodality growth. 2006.* Available at: http://www.transport-research.info/Upload/Documents/ 200608/20060831_100031_82868_intermodal_freight.pdf
19. *GYS Dynamic Maps – TENtec.* Available at: http://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/main.jsp
20. *Priority Project 2*. Available at: http://inea.ec.europa.eu/en/ten-t/ten-t_projects/30_priority_projects/priority_project_2/priority_project_2.htm
21. *Priority Project 13*. Available at: http://inea.ec.europa.eu/en/ten-t/ten-t_projects/30_priority_projects/priority_project_13/priority_project_13.htm
22. *Priority Project 14*. Available at: http://inea.ec.europa.eu/en/ten-t/ten-t_projects/30_priority_projects/priority_project_14/priority_project_14.htm
23. *Priority Project 26*. Available at: http://inea.ec.europa.eu/en/ten-t/ten-t_projects/30_priority_projects/priority_project_26/priority_project_26.htm
24. *Priority Project 28*. Available at: http://inea.ec.europa.eu/en/ten-t/ten-t_projects/30_priority_projects/priority_project_28/priority_project_28.htm

25. *Priority Project 30.* Available at: http://inea.ec.europa.eu/en/ten-t/ten-t_projects/30_priority_projects/priority_project_30/priority_project_30.htm
26. *Inland Waterways.* Available at: http://www.green-ten-t.eu/act-smart/inland-waterways/
27. *Waterways – the key ingredient for better mobility* . Available at: http://www.inlandnavigation.eu/what-we-do/eu-policy/
28. *The geography of transport systems*. Available at: https://people.hofstra.edu/geotrans/eng/ch4en/conc4en/typesintermodalterminals.html
29. *Inland Rivers, Ports, and Terminals, Inc.* Available at: http://www.irpt.net/information/
30. *Eurostat*. Available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/
31. *DataMarket. Find, understand and share.* Available at: https://datamarket.com/

Received 10.07.2014; accepted in revised form 02.10.2014