THIS IS A PRE-PRINT COPY. THE FINAL VERSION IS AVAILABLE AT: https://doi.org/10.1016/j.trpro.2021.07.116

14th International scientific conference on sustainable, modern and safe transport

Developing a Prototype Platform To Manage Intelligent Communication Systems in Intermodal Transport

Maria Giuffrida[a]*, Sara Perotti[a], Angela Tumino[a], Vincenzo Villois[b]

[a]*Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Via Lambruschini 4B, 20156, Milan, Italy*
[b]*TESISQUARE®, Via Savigliano, 48, 12062, Roreto di Cherasco (Cuneo), Italy*

Abstract

Due to the collective attention towards global environmental challenges, the rise in fuel prices, the risk of drivers' shortage, and the new legal developments limiting the hours of service on frequently congested roads, developing efficient and effective intermodal freight transport networks is becoming an increasingly important success factor for companies to manage their supply chains. However, many factors hinder the smooth implementation of intermodal systems, such as the high number of operators to be involved, the duplication of handling activities and transit times at the intersection of each transport mode, and the lack of information sharing among the different transport modes and companies. To overcome such barriers, Intelligent Communication Systems (ICS) have increasingly been applied to activities within the nodes (warehouses, transit points) and arches (transport routes) of distribution networks, providing several benefits, such as real-time visibility and tracking, more precise, reliable and efficient data collection, and document exchange. One of the key elements that can guarantee the successful design and implementation of an intermodal transport system is the integration of the various systems and actors involved along the process. This paper aims to contribute to this issue by presenting some of the results of the "ITS Italy 2020" project, an applied research initiative financed by the Italian Government to foster the diffusion of Intelligent Transport Systems (ITS). More specifically, we illustrate a prototype solution, based on a software that allows managing and monitoring freight transport along an intermodal network, thus overcoming some barriers currently limiting intermodal transport implementation. The prototype can communicate with devices and sensors put on board the vehicle or load, and track sensors positioned along the road. The solution integrates all the other systems involved by collecting and publishing information, managing events, and sending messages.

Keywords: Intelligent Transport Systems; Intelligent Communication Systems; Intermodal Transport; Logistics; Platform; Prototype

* Corresponding author. Tel.: +39 02 2399 3950
E-mail address: maria.giuffrida@polimi.it

1. Introduction

The climate change and the consequent increasing attention towards severe environmental challenges, together with the rise in fuel prices, road congestion and the frequent road accidents are amongst the main reasons why intermodal freight transport is continuously considered a key distribution model in the global landscape. Although the earliest contributions in this field date back to the early 1990s (Agamez-Arias and Moyano-Fuentes, 2017), intermodal transport is far from being considered "old-fashioned". On the contrary, it still attracts the attention of many researchers and practitioners. By combining the use of different transport modes within the same journey, intermodal transport networks have the potential to leverage on the advantages of each mode and bring large benefits in terms of cost, time, and environmental impact to both single companies and the external environment (Carboni and Dalla Chiara, 2018). This entails serious commitment and willingness to cooperate of the various actors engaged (Flodén and Williamsson, 2016).

The challenges behind the design and management of an intermodal system are indeed numerous, but one of the biggest issues is the integration among the various systems and actors involved along the process. A proper use of communication technologies can help reduce this problem. However, the availability of adequate technological solutions to support intermodal transport is still below its potential in some countries (European Commission, 2019). Italy, in particular, is still working to develop and adopt digital solutions in many industrial sectors, including logistics and transport. Due to its geographical specificities, however, it represents an interesting location for the development of logistics networks, including intermodal ones.

In order to foster the diffusion of Intelligent Transport Systems (ITS) for intermodal transport in this country, a large research project was therefore launched involving both academicians and practitioners. This paper presents some of the results of this project by focusing on a newly developed prototype platform that can manage and monitor freight transport along an intermodal network, thus overcoming some barriers currently limiting intermodal transport implementation.

The paper is developed as follows: the next section presents a short overview of literature contributions in the field of interest. Afterwards, the applied methodology is described, together with the results of the research. The last section concludes and highlights future research opportunities.

2. Literature review

2.1. Intermodal transport

Intermodal transport is a specific type of delivery model relying on different transport means, where goods are moved through reusable transport and storage units (e.g. trailers, semitrailers, swap bodies, containers) that are not deconsolidated during the entire process (Marchet et al., 2012). This model has received increasing attention in the past few years, especially in reaction to the several negative effects caused by an over-use of road transport, such as pollution, congestion and accidents (Islam, 2014; Zgonc et al., 2019). The European Commission, for instance, has promoted several directives - including the amendment of the Combined Transport Directive in 2013 and the issue of the Weights and Dimension Directive in 2015 - to encourage the adoption of intermodal transport solutions. Also, many financing opportunities were provided for research projects focused on intermodal and multimodal transport within the Connecting Europe Facility Transport Programme and Horizon 2020 Framework.

Current literature provides abundant contributions on intermodal transport. The earliest research dates back to the early 1990s. As reported by Agamez-Arias and Moyano-Fuentes (2017), the first decade of investigation in this field was mainly focused on specific planning and modelling problems arising with the intermodal concept (e.g. Macharis and Bontekoning, 2004). Later, the focus was shifted towards the understanding of intermodal challenges in specific contexts or geographical areas (e.g. Mathisen and Sandberg, 2014). More recently, new policy developments and future technological advancements have started to be discussed in intermodal transport literature (e.g. Harris et al., 2015; Ben-Daya et al., 2017).

Regardless the specific focus or perspective adopted, many of the extant papers tend, however, to agree on a set of key discussion points related to both the advantages and disadvantages of this system. On one side, the intermodal approach is considered particularly suitable for international shipments to organise the entire delivery process within an integrated system, characterised by more efficient and cost-effective operations (Harris et al., 2015). These advantages are possible because, by definition, intermodality captures the benefits of each transport mode, e.g. the flexibility of road haulage, the large capacity of sea freight, the reduced environmental impact of railways (Eng-Larsson and Kohn, 2012; Harris et al., 2015). On the other side, despite such advantages, the adoption of intermodal transport systems is not as extensive as we could expect, due to a series of complications. Among these, the high number of players involved and the need for integrating their physical and information flows throughout the entire delivery process are major barriers (Marchet et al., 2009). The overall process is indeed very long and composed of a series of necessary activities that should be managed as seamlessly as possible and that range from contractual agreements, to delivery planning, administrative and legal compliance, transport execution, quality control and, if needed, also customs clearance (Harris et al., 2015).

2.2. Intelligent Transport Systems supporting intermodality

Information and Communication Technologies (ICTs) have long been considered key enablers of effective logistics and supply chain management (Ross, 2016). The main reasons why technologies have a major impact on the nature and structure of supply chains lie in their ability to provide both internal integration of various processes and external integration with suppliers and customers. Increased integration is reached by improving data collection and sharing, communication, monitoring, control and tracking. All these elements allow a better detection of problems and management of uncertainties or risks. This, in turn, enables more effective decision-making and enhanced supply chain performances (Ben-Daya et al. 2017). To allow the intermodal transport system to be fully sustainable, it is crucial that the adopted ICTs move from being developed in a closed system environment to becoming a truly open and integrated system. This is the main challenge behind an ITS. Many contributions in literature discuss the potentialities of ITS to improve the mobility of both freight and people within cities, relying on innovative solutions that combine different technological trends, such as Internet of Things, Blockchain, and Cloud (e.g. Mangiaracina et al., 2017, Wang et al., 2019).

All the studied contributions also recognise the impact that ITS could have on intermodal transport which, as previously mentioned, largely suffers from integration problems. At the same time, most of the existing papers in this field have a theoretical or conceptual nature, presenting literature reviews or general reviews. However, a more empirical or practice-oriented approach is still scarce. Based on these considerations, this research aims to support the development of comprehensive technological solutions that can enable effective and efficient intermodal systems.

3. Methodology

This study is part of a larger multi-year project on ITS supporting logistics and, more specifically, freight transport processes. The overall research (named ITS Italy 2020) has involved a large ecosystem of Italian universities and companies who have fruitfully cooperated to study and develop four main types of innovative solutions, summarised in Figure 1: integrated smart sensing to support transport processes or warehouse operations, and data communication systems to support transport processes or warehouse operations.

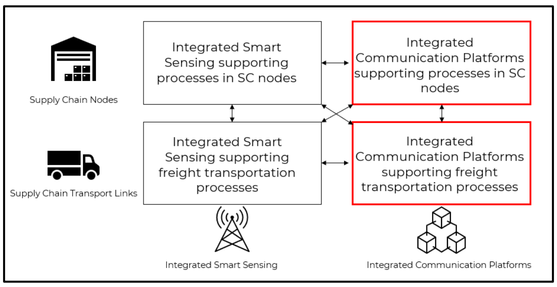

Fig. 1. Research framework of the ITS Italy 2020 project.

The research here presented is focused on the right-hand section of the framework above (highlighted in red) and was developed along the three main phases described hereafter.

- **Phase 1 - Literature review**: a review of existing contributions in the ITS domain, with a focus on intermodal freight transport and its enabling technologies was conducted in the initial phases of the study. A summary of the main results of the review have been already presented in the literature section of the paper. This phase helped understand the state of the art and position our research within a relevant research gap, i.e., the problem of integrating different communication and transport systems involved in intermodal freight transport.
- **Phase 2 - Mapping of intermodal transport processes through empirical analysis**: to better define the scope of the research project, a detailed description of the intermodal transport process was developed, relying on interviews with companies and logistics operators. Starting from the processes mapped in the description, the operations, events, and states that could hinder the smooth execution of the process were identified. A set of critical aspects that should be subject of more in-depth investigation and whose performances could be improved via the development and application of technological solutions was also detected. The mapping was conducted based on the assumption that the intermodal process consists of a set of transport sections (arches) connecting terminals (nodes), where each transport section can be covered by different transport modes, namely, sea, land, and railway. The terminals work as exchange nodes to shift from one transport mode to another.
- **Phase 3: Development of the prototype:** finally, a prototype of a platform was developed, able to manage and track freight transport along the intermodal network identified in the previous phase. At this stage, some assumptions were necessary, as the objective of a prototype is to exemplify the potential effects and main properties of a solution in a simplified environment. Therefore, only the travel phase was considered, while the activities occurring before the travel (e.g. planning and preparation) were discarded. Similarly, administrative activities or negotiations with transport service providers were not included in the prototype. Additional assumptions were made regarding the detail of the mapped activities and functionalities. All these features are discussed in the results section.

In line with the nature of the ITS Italy 2020 project, this study was conducted by a mixed panel of authors. Academic researchers and professors curated the literature analysis, process mapping and research design sections, while one of the partners representing the practitioner community, namely TESISQUARE®, a provider of collaborative technological solutions, led the prototype development phase.

4. Results and Discussion

4.1. Mapping of intermodal transport processes through empirical analysis

A mapping of the stages of the intermodal transport process involving road, rail and sea routes is proposed to describe how the different transport modes are correlated as well as the main players involved. In line with the objectives of this research project, air and inland water transport are excluded from the analysis. A simplified graphical representation of the intermodal process is offered in Figure 2. The process begins with the signing of the sales contract between the seller (sender or shipper) and the buyer (recipient or consignee) and ends with the delivery of the goods to the recipient.

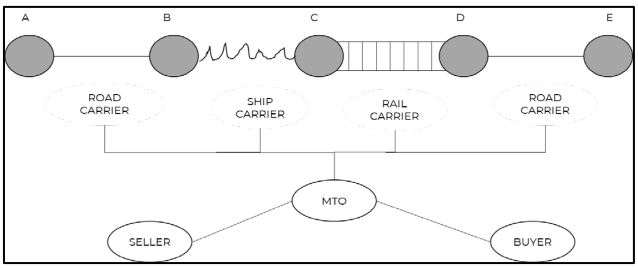

Fig. 2. Intermodal Transport Process: main phases and players involved

The process consists of three main stages. The first one is a contractual phase, where the main actors are the seller and the buyer. The second one is the planning phase, where the central role is played by the Multimodal Transport Operator (MTO), an intermediary that offers a fully outsourced door-to-door transport service with a single commercial offer, directly managing the relationship with different carriers. The last stage is transport, where carriers and terminal operators are involved.

In the contractual stage, the following activities take place:

- **Seller - Buyer: stipulation of the Sale and Purchase Agreement.** At the base of freight forwarding, there is a Sale and Purchase Contract stipulated between the seller and the buyer with the aim to transfer the ownership of the goods covered by the contract from the seller to the buyer. With this contract, obligations arise for the buyer and the seller. In this sense, the contract must specify to what extent the risks and costs of transport fall on the seller or on the buyer, based on the selected INCOTERMS® agreements.
- **Seller - MTO: stipulation of Contract of Carriage.** The seller signs a multimodal Contract of Carriage with the MTO who does not physically carry out the carriage but enters "single mode" sub-contracts with the carriers actually taking part in the carriage process. However, for some transport segments, the MTO may also use its own resources.
- **MTO - Buyer: sending the Multimodal Transport Document.** The MTO sends the transport contract to the consignee in order to provide him/her with the receipt to collect the goods on arrival.

The planning stage develops as follows:

- **MTO - Road carrier: request for road transport service.** The MTO and the road carrier sign a sub-contract of carriage. In this contract, the MTO provides the road hauler with the indications on the time and place where the goods will be loaded, together with other information of interest. When loading the goods, the MTO must provide the carrier with the road waybill.
- **MTO - Shipping Company: reservation of ship spaces.** The MTO makes a reservation with the shipping company to ensure enough space for the ship transport section by means of a document called booking note.
- **MTO - Intermodal Operator: rail transport service request.** The MTO sends a request to the intermodal operator for the provision of the wagons necessary for the railway transport of the established route.
- **MTO - Container depot: Intermodal Transport Units (ITUs) request.** The MTO sends a request for empty containers to the container depot; based on the information provided by the shipper, (s)he determines the number and type of containers needed to carry out the transport.
- **MTO - Shipping Company - Port Terminal: port terminal access booking.** Based on the order received by the MTO, the Shipping Company notifies the departure port terminal of the need for a container transhipment service from the land mode (road or rail) to the sea mode and, similarly, it notifies the arrival port terminal of the need for a transhipment service from the sea mode to the land mode (road or rail).
- **MTO - Intermodal Operator - Intermodal Terminal: booking access to the intermodal terminal (Inland Terminal).** On the basis of the assignment received by the MTO, the intermodal operator ensures that the intermodal terminal is available to carry out a transhipment of containers from road to rail (or vice versa), on the requested date and time.

Finally, the actual transport takes place according to the following steps:

- **Road Carrier: picking up Intermodal Transport Units (ITUs) and loading goods**. The road carrier picks up the ITUs and loads them as per the agreements with the MTO. Once all the necessary formalities have been completed, the carrier can set off in the direction of the terminal where the change of mode will take place.
- **Road Carrier - Intermodal Terminal: access to the intermodal terminal (port or inland).** The road vehicle arrives at the intermodal terminal; checks are carried out on the ITUs and, if no anomalies are found either from the bureaucratic (waybill and necessary documentation) or technical (e.g. damage to ITU) point of view, the operator allows the transshipment operations.
- **Ship Carrier - Port Terminal: communication of ship loading programme.** The shipping company informs the port terminal of departure about the goods to be loaded on the ship ("loading list" and "master bay plan"), thus specifying the containers to be loaded and the loading order in which the containers are to be loaded. Once the goods have been loaded on the ship, the shipping waybill is drawn up. The port terminal of destination will consequently receive similar information to accompany the landing order.

- **Intermodal Operator - Train Operator: preparation of train departure from the intermodal terminal.** The intermodal pperator sends the railway waybill to the train operator who, in turn, provides the train departure data and the expected time of arrival (ETA) of the shipment at the next terminal. The railway consignment note must contain all the information necessary to transport the cargo from the shipper to the consignee. Once the formal activities have been completed, the train can start its journey towards the next terminal.

4.2. Critical areas and intervention priorities

After in-depth examination of the intermodal process above described, and based on interviews with MTOs, over 20 different types of criticalities and operative needs affecting intermodal transport performances were identified and clustered in macro-areas: load management, information and document flow management, terminal operations management, vehicles and infrastructure maintenance, traceability, monitoring of vehicle and freight parameters. Some examples include the need to optimise the train composition according to wagon characteristics and load requirements in the node, the need to reduce the exchange of documents between actors, the need to standardise information flows, and promptly identify critical situations, bottlenecks or vehicle anomalies for maintenance and safety purposes. Additional necessities refer to the real-time monitoring of humidity and temperature inside ITUs, as well as the acquisition of accurate and complete ITU location information throughout the transport cycle.

4.3. Development of a prototype cooperative communication platform for intermodal transport

To address some of the major issues identified both in the literature and the empirical analysis (i.e. interviews with companies), a prototype of a communication platform was developed. This tool has the main objective to manage an intermodal logistics network consisting of a main transport segment carried via ship, secondary transport segments via rail and train, and intermodal nodes.

For pure demonstration purposes, the prototype has been developed only with reference to the transport phase, as anticipated in the methodology. More specifically, the following transport activities are tracked: exit from the starting node, travel, and arrival at the destination node. In addition, the following activities are monitored within the intermodal nodes: unloading of the ITUs, handling of the ITUs inside the node, and loading of the ITUs on the next transport mode.

This prototype solution is part of a network consisting of software and hardware components that perform specific tasks without necessarily dialoguing with each other. Relying on the platform, developed by TESISQUARE®, a specialised provider of collaborative solutions, the integration problems can be solved. The platform indeed presents functions that allow the visualisation of dashboards, documents and KPIs provided in real time. The communication between the platform and the other multiple systems involved is supported by a web service based on an open architecture developed with other partners of the project.

The prototype allows the following main functions:

- Providing visibility of trip planning and structure
- Tracking the trip and give evidence of its status
- Monitoring and receiving the status of the ITUs, detecting some parameters, such as location, temperature and humidity
- Providing evidence of events related to node activities
- Receiving/sending messages related to the On Board Units (OBUs) status
- Receiving trip coordinates

The platform can be accessed via username and password by all the players involved in the process and previously mentioned, i.e. the MTO, the seller, the buyer and the various carriers or intermodal terminal operators. However, each of them has different roles within the platform, thus limiting or extending some of the available functions. For instance, the MTO can track the entire journey and access the planning function, while the carriers can track only the portion of transport under their ownership. The orders can be filtered or ranked by date of departure or arrival. All the shipments belonging to the same intermodal route can be easily isolated since they are identified by a similar code (the initial letters of the ID are the same). The data about journeys and deliveries can be extracted into spreadsheet files to allow more detailed analyses.

For instance, considering an MTO as a user with full visibility on the entire delivery process, the navigation on the platform starts by inputting the delivery dates of interest. After confirmation of the required time window, the expected deliveries on those dates appear. By clicking on those deliveries, the platform will give the possibility to see further details on each shipment and to modify the status of the delivery when it reaches the subsequent phase.

For explanatory purposes, Figure 3 provides an example of additional information available on the platform. The graph generated reports the trend of the freight temperature over time, compared with the expected minimum and maximum temperature parameters for the considered type of good. A similar report can be generated with reference to humidity data and all the key events connected with the status of the ITUs (e.g. exit from warehouse, arrive at terminal, loading or unloading) and their location.

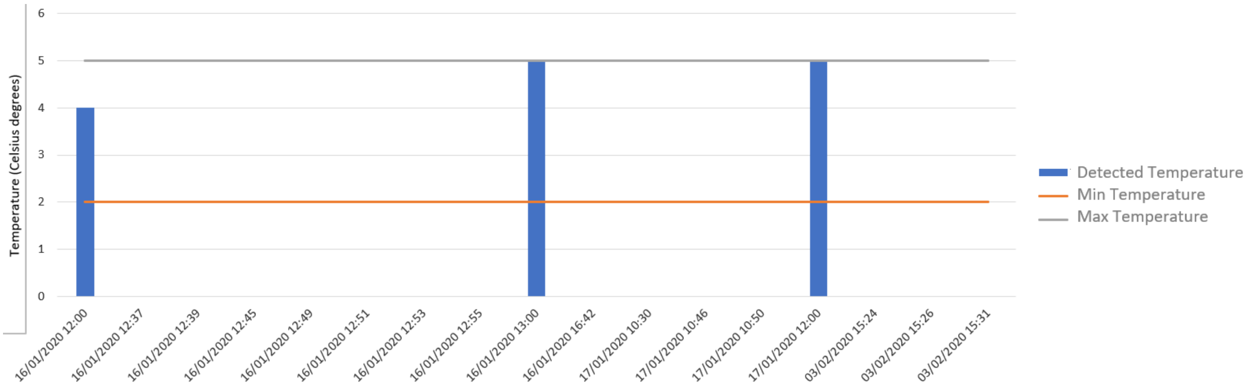

Fig. 3. Sample data analysis visualisation – Temperature monitoring

The value of this solution is that it allows extracting data from a large network of software and hardware components executing specific tasks without necessarily being connected to each other. Therefore, this prototype is natively a collaborative solution that allows overcoming the lack of integration problems recognised by literature in the intermodal transport field (e.g. Agamez-Arias and Moyano-Fuentes, 2017; Boehm et al, 2021; Harris, 2015; Islam, 2014).

5. Conclusions

The present study investigates the intermodal transport process. The research presents the prototype of a newly developed open platform to manage and track ITUs along the overall journey and within the network nodes. This research can be viewed as a virtuous example of cooperation between industry and academia, jointly working to provide knowledge that has both theoretical relevance and practical impact. From a theory perspective, the study addresses a well debated literature research issue, that is the problem of providing integration among all the players involved in the intermodal process. From a practical viewpoint, the study contributes with the development of a prototype solution that can improve intermodal transport management. The development of innovative solutions for logistics is very important, especially in the Italian context which, according to the Digital Economy and Society Index (DESI) in 2020, still suffers from a lag in the level of digitalisation with respect to other European countries. The results here presented can reveal useful insights to interested researchers and practitioners, such as the full description of an intermodal transport process, the identification of the key challenges to face and the proposal of a technological platform to reduce these challenges. To further improve and strengthen the value of the results in the future, we suggest removing some of the boundaries here considered. To name a few, we have for instance neglected the considerations about customs clearance procedures. A more advanced version of this study could complement the intermodal network by also considering plane-based transport, which is consistent with the implementation of intermodal systems across different continents and customs jurisdictions.

Acknowledgements

This study is part of a broader research and was developed within the context of the "ITS Italy 2020" project funded by the Italian Ministry of Education, University and Research.

References

Agamez-Arias, A.D.M., and Moyano-Fuentes, J., 2017. Intermodal transport in freight distribution: a literature review, Transport Reviews, 37.6, 782-807.

Ben-Daya, M. Hassini, E., and Bahroun, Z.,2019. Internet of things and supply chain management: a literature review, International Journal of Production Research, 57.15-16, 4719-4742.

Boehm, M., Arnz, M., and Winter, J., 2021. The potential of high-speed rail freight in Europe: how is a modal shift from road to rail possible for low-density high value cargo?, European Transport Research Review, 13, 1-11.

Carboni, A., and Dalla Chiara, B., 2018. Range of technical-economic competitiveness of rail-road combined transport, European Transport Research Review, 10.2, 1-17.

Eng-Larsson, F., Kohn, C., 2012. Modal shift for greener logistics – the shipper's perspective, International Journal of Physical Distribution and Logistics Management, 42.1, 36-59.

European Commission, 2019. Transport in the European Union – current trends and issues: Report, March 2019.

Flodén, J., and Williamsson. J. 2016. Business models for sustainable biofuel transport: the potential for intermodal transport, Journal of Cleaner Production, 113, 426-437.

Harris, I., Wang, Y., Wang, H., 2015. ICT in multimodal transport and technological trends: Unleashing potential for the future, International Journal of Production Economics, 159, 88-103.

Islam, D. M. Z., 2014. Barriers to and enablers for European rail freight transport for integrated door-to-door logistics service. Part 1: Barriers to multimodal rail freight transport, Transp Probl, 9, 43–56.

Macharis, C., and Bontekoning, Y., 2004. Opportunities for OR in intermodal freight transport research: A review. European Journal of Operational Research, 153.2, 400–416.

Mangiaracina, R., Perego, A., Salvadori, G., Tumino, A., 2017. A comprehensive view of intelligent transport systems for urban smart mobility, International Journal of Logistics Research and Applications, 20.1, 39-52,

Marchet, G., Perego, A., Perotti, S., 2009. An exploratory study of ICT adoption in the Italian freight transportation industry, International Journal of Phyical Distribution and Logistics Management, 39.9, 785-812.

Marchet, G., Perotti, S., Mangiaracina, R., 2012. Modelling the impacts of ICT adoption for inter-modal transportation. International Journal of Physical Distribution and Logistics Management, 42.2, 110–127.

Mathisen, T. A., and Sandberg, T.-E., 2014. The academic literature on intermodal freight transport. Transportation Research Procedia, 3, 611–620.

Ross, D. F. 2016. Introduction to Supply Chain Management Technologies. Boca Raton, FL: St Lucie Press.

Wang, Y., Han, J.H., Beynon-Davies, P., 2019. Understanding blockchain technology for future supply chains: a systematic literature review and research agenda, Supply Chain Management, 24.1, 62-84.

Zgonc, B., Tekavčič, M., and Jakšič, M., 2019. The impact of distance on mode choice in freight transport, European Transport Research Review, 11, 10.