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Multimodal Freight Transport Planning: a Toolbox Supporting Participants Collaboration

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This paper aims to analyse the planning of chemical transports shift from road to the more complex multimodal freight transport, and presents a toolbox developed to support the participants in the process. In literature the research problem of multimodal freight transport planning is analysed mainly from mathematical models' perspective. There is a lack of studies focused on multimodal transport chain collaboration and the tools supporting it. Within the framework of research conducted during the ChemMultimodal „Promotion of Multimodal Transport in Chemical Logistics" project, within INTERREG Central Europe Programme, the research team identified challenges related to modal shifts in the chemical industry, and next developed the toolbox addressing these challenges and supporting participants' collaboration on multimodal chemical freight transport planning. The toolbox embraces: (1) consulting services, (2) planning guidelines, (3) the Intermodal Links platform, which suggests intermodal connections between two points, and (4) a CO2 calculator. Conclusions from the first pilot tests showed the necessity of a complex approach to the process of modal shift planning. Transport managers testing the toolbox the most appreciated the consulting services, which include a marketing platform integrating chemical producers and distributors, logistics companies, carriers, terminal operators, rail network operators and others. This platform is used to share information on current transport patterns, existing potentials, and possible actions to establish and promote modal shift.

Keywords: sustainability, intermodal transport, cooperation, logistics service provider (LSP), chemical logistics

1. INTRODUCTION

In the last decade, multimodal transport in general, and intermodal transport in particular, have received more attention from both practitioners and academics. On the one hand, the increasing transport demand, the overloaded transport networks as well as environmental factors like climate change or limited resource availability (ITF, 2017) push the European Commission and governments to promote the development of a more efficient, sustainable, and environmentally friendly European transport system (COM, 2011). On the other hand, new technological developments strongly influence the field of transport logistics, offering a wide spectrum of improvement opportunities, including an improved transport planning process (BVL, 2017).

One of the most prominent targets of the EU Transport Whitepaper is the ambition to shift 30% of road freight, transported more than 300 kilometres, to multimodal by 2030, and 50% by 2050. Transport and logistics industries are working on achieving this goal with strong commitment and contribution from chemical companies.

The purpose of the study is to analyse the planning of chemical transports' shift from road to more complex multimodal freight transport, and to find answers for the following research questions: Who are the main actors within the process of chemical freight modal shift from road to multimodal transport with main haulage done by rail? What are the main challenges within the modal shift? Are there any tools supporting the participants of the modal shift process? How to facilitate supply chain and logistics partners' collaboration on shift to multimodal transport? Is a toolbox with IT tools facilitating modal shift able to increase the usage of multimodal transport by chemical and logistics companies?

The empirical research to answer these questions is a part of the "Promotion of Multimodal Transport in Chemical Logistics" project run within the framework of INTERREG Central Europe Programme. The project is one of key logistics and chemical industries' responses to expectations and goals as set in the EU Transport Whitepaper. Its main objective is the promotion of multimodal transport of chemical goods by coordinating and facilitating cooperation between chemical companies, specialised logistics service providers (LSPs), terminal operators, and public authorities in chemical regions in CE.

Following the introduction the paper is divided into four more sections. Section 2 presents a literature review providing the theoretical basis of the analysis. It is focused on multimodal transport planning and its complexity, presents an overview of modelling tools used to support the multimodal transport decision maker, and ends with presenting the need and framework for supply chain and logistics collaboration when shifting chemical freight from road to multimodal. Section 3 is dedicated to the method of research with a description of the toolbox development and testing as the main part. Section 4 presents the results and its discussion. Conclusions and implications for further research and practice are in Section 5.

2. LITERATURE REVIEW

The literature review is used to frame the analysis. It focuses on two aspects: (i) multimodal freight transport planning complexity, and (ii) how decision makers can deal with this complexity by collaborating on multimodal transport systems in logistics alignments.

2. 1. COMPLEXITY OF MULTIMODAL TRANSPORT PLANNING

Different terminologies circulate in the literature and in the industry to describe the phenomenon of transportation using more than one mode. Very often they are used interchangeably, but according to the European Conference of Ministers of Transport (ECMT) and the United Nations (UN) Convention on International Multimodal Transport of Goods they differ and they should be understood as follows (OECD, 2003).

Multimodal transport refers to use of more than one mode of transport. **Intermodal transport** is a type of multimodal transport organised in one and the same loading unit (e.g. a TEU container) or vehicle by successive modes of transport without the handling of the goods themselves when changing modes (OECD, 2003; Reis et al., 2013; SteadieSeifi et al., 2014). **Combined transport** is intermodal transport where the major part of the European journey is by rail, inland waterways, or sea, and any initial and/or final leg that is carried out by road is as short as possible.

In 2006 the European Commission introduced the concept of **co-modality** and defined it as being focused on 'the efficient use of resources within different modes on their own and in combination' (EC, 2006, p. 4). It means that transport modes are used in a smarter way to maximize the benefits of all modes, in terms of overall sustainability (Cruijssen, & ArgusI, 2012; SteadieSeifi et al., 2014).

Synchromodal transport is positioned as the next step after intermodal and co-modal transport, and involves a structured, efficient, and synchronized combination of two or more transport modes. Synchromodal transport emphasises real-time flexibility, when carriers select independently, at any time, the best mode based on the operational circumstances and/or customer requirements (Verweij, 2011; SteadieSeifi et al., 2014).

Multimodal transport, as the broadest definition that embraces the other notions, was taken as the base for the literature review. The research was limited to multimodal freight transport. Multimodal freight transport occurs in an environment shaped by **multiple participants** (Crainic & Hewitt, 2017):

- *shippers* (e.g. manufacturers, distributors, wholesalers, and retailers) who create demand for transportation services in the form of a request for transport between two points; in the European chemical industry more than 90% of chemical transport is outsourced to logistics service providers (LSPs) (McKinnon & Piecyk, 2010) and such requests for freight transport, in most cases, does not come directly from the shipper, but instead through an LSP or freight forwarder;
- *carriers* who supply the transport to move freight, and the organisations supporting them: i.e. infrastructure operators (e.g. terminal operators, rail network operators), rail wagons, containers, swap bodies, or semi-trailers owners, etc.

- *government institutions* who provide or influence the physical infrastructure (e.g. rail tracks) that carriers rely on to provide transport services, and regulate multimodal transport market where supply is matched with demand.

Each of these participants has a different perspective on multimodal freight transport and, consequently, a different set of KPIs. Multimodal transport compared with road haulage has also some other inherent challenges, such as longer transit times, lower reliability and flexibility, and **the need to reconfigure the supply chain to incorporate potential changes in the system,** such as increased in-transit inventory and extended delivery windows. To address and manage these challenges, increased collaboration on planning, executing, and controlling is needed between key participants.

Floden et al. (2017) reminds that when designing and evaluating such a complex system, modelling is an important part of the decision-making process, as models are tools that help one to make informed decisions about transport systems and reduce the risk of failure (p. 214). However the complexity of the system makes simplifications and assumptions necessary in the modelling. It is therefore important to understand the model as well as the assumptions made when interpreting the results.

2. 2. MODELLING OF MULTIMODAL TRANSPORT SYSTEMS AS A TOOL SUPPORTING DECISION MAKERS

According to Floden et al. (2017), models are used on several levels of multimodal or intermodal transport systems. After Wandel et al. (1992) they divide it into: freight flows, transport network and transport infrastructure and add *decision horizon,* which provides three main types of models, i.e. operational, tactical, and strategic models. Table 1 presents different types of models and corresponding decision types with their characteristics and examples.

Floden et al. (2017) emphasises that multimodal or intermodal transport modelling systems are available in different sizes. The simplest ones are just Excel spreadsheets, while other models are advanced, stand-alone modelling systems. There are *agent-based models* (ABMs), simulating the behaviour of customers, transport chain coordinators, product buyers, transport buyers, production planners and transport planners, used in transport modelling. Similar to real life, not all actors in these ABMs interact; nevertheless the model can simulate the different transport agent's reactions on the implemented policy.

Crainic and Hewitt (2017) differentiate between *prescriptive* and *predictive models*. The former ones are those that yield the set of decisions that are the best with respect to a KPI, when the latter ones predict the value of KPIs interest given a set of decisions.

A very complex literature review, which focused on conceptual and mathematical transport planning models, is presented by SteadieSeifi et al. (2014). They also structure their analysis around three classical levels of planning i.e. strategic, tactical, and operational planning.

- **Strategic planning** problems relate to long-term investment decisions on the present infrastructure (networks). They use a variety of models related to consolidation. In the literature, consolidation systems are mostly configured as hub-and-spoke networks, with hub being a freight handling (consolidation) facility. These problems are called *hub location problems*. In the literature, the hub location problem is commonly modelled as hub median or hub centre problems (Meyer, Ernst & Krishnamoorthy, 2009). The main objective of hub median problems is to minimise total transportation

Table 1. Model and decision type (based on Floden, 2017)

Level	Decision type	Decision characteristics	Information characteristics	Example
Strategic	Unstructured	Ad hoc, infrequent, lack of detailed data support	Wide scope, summarised, specialised	Should we start an intermodal service in the foreign market?
Tactical	Semi-structured	Combines structured and unstructured decision making	A mix of data intense, detailed data and wide scope unstructured data	Which rail operator should we use?
Operational	Structured	Predictable, rational, frequent, narrow focused	Data intense, detailed	How to best calculate the routing of vehicles?

cost. Hub location problems are sometimes modelled as *hub-covering problems* where the objective function is to maximise the total number of served spoke nodes (Alumur & Kara, 2008).

- **Tactical planning** problems deal with optimally utilising the given infrastructure by choosing services and associated transportation modes, allocating their capacities to orders, and planning their itineraries and frequency. In the literature on tactical planning problems, mostly hub-and-spoke structures are regarded. There are two groups of models: *Network Flow Planning (NFP)* related to the flow planning decisions and addressing the movement of orders (commodities) throughout the network, and *Service Network Design (SND)*, involving the service planning decisions including all decisions on choosing the transportation services and modes to move those commodities. SND problems are furthermore partitioned into *static* (Ayar & Yaman, 2012) and *dynamic problems* (Wieberneit, 2008). While in both groups one determines the frequency of the service, the capacity allocation, the equipment planning, and the routing and flow of commodities, in the former it is assumed that all problem aspects are static over the time horizon, and in the latter, at least one feature (e.g. demand) varies over time.
- **Operational planning** deals with dynamicity and stochasticity that are not explicitly addressed at strategic and tactical levels. These problems relate to real-time planning for orders, and reaction and adjustment to any kind of disturbance (e.g. accidents, weather changes, or equipment breakdowns). Most of these system elements vary with time and show a non-deterministic behaviour. Current decisions depend on both the present information and an estimation of the future, and the objective is not only to minimise the costs, but also to maximise reliability of the system. There are: (i) *Resource Management* problems which deal with the distribution of all resources throughout the network: positioning, repositioning, storing, and allocating them to customer orders (e.g. Chang et al., 2008) and (ii) *Itinerary Re-planning* problems which are focused on real-time optimisation of schedules, modal routes, and the relevant response to operational disturbance (e.g. Goel, 2010; Bock, 2010). Resource management and itinerary re-planning problems are in practice intertwined and act as two components of a bigger operational planning problem.

Due to the complexity of multimodal transport, the **models are rarely used to directly manage the system**, but rather **as support tools** which should be combined with other data sources and the decision maker's experience. In complex systems, such as multimodal transport, the **critical successes factor becomes partners' collaboration**. It is recognised as the way to master the complexity of the supply chain.

2. 3. COLLABORATIONONMULTIMODAL TRANSPORT PLANNING

In this paper, **supply chain collaboration** is defined as 'a high level of integration between two companies working together to create a competitive advantage and higher profits than could be achieved by operating alone' (Soosay & Hyland, 2015). However, not all cooperation is collaboration. Świtała (2015) grades inter-firm relationships on a scale from cooperation, through coordination, up to collaboration when collaborating companies treat each other as an 'extension' of their organisation.

Designing a supply chain and logistics collaboration framework (e.g. on green logistics or logistics innovation), a company should decide on: (i) the appropriate partner to collaborate with, (ii) the plethora of logistics activities constituting the 'width' of logistics collaboration, and (iii) the level of supply chain integration referred as the 'depth' of the relationship (Cichosz, 2017).

Much supply chain and logistics literature has addressed **the key requirements in supply chain and logistics collaboration** (e.g. Cao & Zhang, 2011). Cichosz (2016), when writing about aligning on collaborative logistics innovation development and implementation, organised these requirement into two groups: **managerial and relational mechanisms**. The former ones are very important for shaping formal structure of alignment and embrace: planning and feedback, senior leadership support, contractual governance with metrics, risk and rewards sharing, and Communication and Information Technology. The list of relational mechanisms embraces mutual trust, relational embeddedness, and relational commitment. Relational mechanisms are very important when partners are working on something new and complex.

Some authors described selected elements from the collaboration requirements' list as techniques useful in relation to development of multimodal or intermodal transport services (e.g. Bergqvist & Monios, 2016).

Collaboration, with its requirements embracing the managerial and relational mechanism, is critical not for regular multimodal transport planning operations (in such cases very often an arm-lengths relationship or cooperation with basic level of supply chain integration is a sufficient option) but rather for more complex situations, such as shifting road freight to multimodal transport. As it was previously mentioned, in most situations modal shift requires supply chain reconfiguration, which is related to increased in-transit inventory and extended delivery windows. In such cases integrating different levels of planning might provide more reliability, flexibility, and sustainability, generating more efficient solutions for the industry (SteadieSeifi et al., 2014). Thus, **creating an environment for supporting partners' collaboration on shifting road freight to multimodal transport is crucial for the growth of multimodal transport.**

from seven countries in Central and Eastern Europe (CEE), i.e. Austria, Czech Republic, Germany, Hungary, Italy, Poland and Slovakia, are working together to improve safety and environmental protection of chemical transports by shifting chemical road freight to multimodal transport, in particular rail. The project is divided into three work packages described briefly in Table 2.

Having completed the analysis of the current situation of intermodal transport of chemicals in partners' countries, and having developed a toolbox for the shift of chemical road transport to multimodal, partners have moved to the second WP dedicated to testing a toolbox in pilot tests. This stage is aimed at improving the methodology of using the toolbox. The final stage of the project is planned as a time for further toolbox promotion as well as for the development of transnational strategy and action plan for multimodality in chemical industry in CEE.

Table 2. ChemMultimodal work packages

Work package	Date	WP description
WP 1	Start: 06/2016 End: 05/2017	*Analysis & Tool Development* **Output:** Tool for promotion of modal shift of chemical goods from road to intermodal transport
WP 2	Start: 06/2017 End: 05/2018	*Pilot Testing* **Output:** Pilot Projects and toolbox implementation in each country
WP 3	Start: 06/2018 End: 05/2019	*Strategy and Action Plan* **Output:** Transnational Strategy (1) and Action Plans (7)

3. RESEARCH METHOD

The research problem is analysed on the basis of a literature review and a 2-stage exploratory empirical research with chemical and logistics companies operating in Poland. The research is part of the "Promotion of Multimodal Transport in Chemical Logistics" project, run within the framework of the INTERREG Central Europe Programme.

3. 1. THE CHEMMULTIMODAL PROJECT

The ChemMultimodal project has been running from June 1st 2016 to May 31st 2019, with a budget of 2.388.840 Euro. Regional authorities, chemical industry associations, and scientific institutions

3. 2. TOOLBOX DEVELOPMENT

In-depth interviews, based on a questionnaire with a mixture of open and multiple-choice questions, were conducted from August to September 2016 with chemical and logistics companies in seven partners' countries. They delivered information about multimodal transportation in chemical industry i.e.:

- Importance and main routes of multimodal transport;
- Potential for modal shift;
- Drivers (advantages) and barriers (disadvantages) of modal shift;
- Potential internal and external improvements in modal shift;
- Relevance of CO_2 measurement.

The results from in-depth interviews provided the framework for the development of a toolbox considering chemical load characteristics. The toolbox is aimed to facilitate cooperation on modal shift in chemical freight transports by creating awareness of intermodal transport importance and presenting possibilities of carrying it out. It connects different participants of the multimodal freight transport process, and supports their collaboration. It consists of four elements: (1) consulting services, (2) planning guidelines, (3) IT visualisation, and (4) CO_2 calculator (Fig. 1).

Each and every part of the toolbox plays an important role in the process of modal shift. *Consulting services* are marketing a platform dedicated mainly for chemical companies to improve their share of multimodal transport. *Planning guidelines* is a list of criteria with regulative national differences, such as loading and driving restrictions, which are required for planning a route of chemical intermodal transport. These are used by a consultant or a facilitator, who helps to develop close cooperation between logistics and chemical companies, to discuss current transport patterns, existing potentials, and possible actions to promote modal shift for chemical loads.

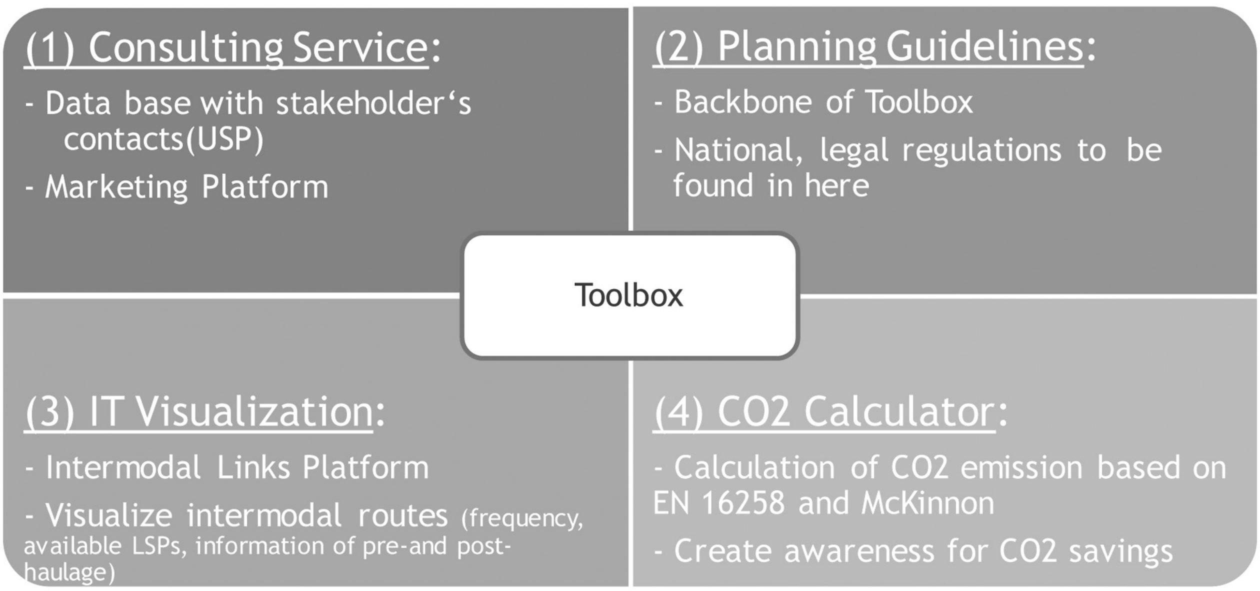

Fig. 1. Toolbox elements (Moritz, 2017)

Fig. 2. Intermodal Links Planner (https://intermodallinks.com/GetAccess)

The *IT visualisation platform* is an easy Intermodal Links Planner (control tower for intermodal transport), which connects data and real-time events to offer companies the best intermodal connections between the place of origin and destination (Fig. 2). It is organised around three steps: (1) inserting the required route, (2) finding the most favourable routes with its graphical illustration, and (3) accessing logistics providers' schedules with other information needed to organise multimodal freight transport.

And last but not least, the *CO_2 calculator* (Fig. 3) which, based on the average emission data calculated by McKinnon (2007), allows for evaluating the effects of the modal shift and estimating CO_2 savings when applying multimodal transport. Data on total transport distance (could be drawn from Intermodal Links Planner), weight of goods, modal split, with distances travelled using each mode of transport, are required data to be able to estimate CO_2 savings with the help of the ChemMultimodal CO_2 calculator.

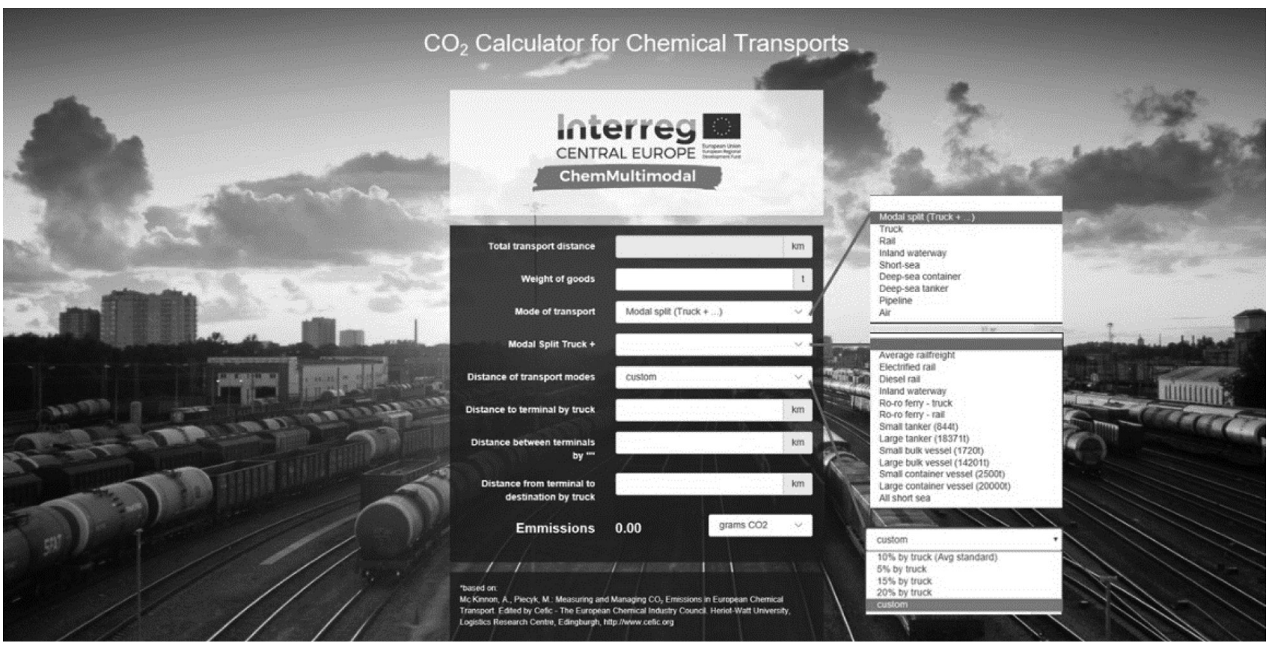

Fig. 3. CO_2 calculator (https://ifsl50.mb.uni-magdeburg.de/chemmultimodal/)

3. 3. TOOLBOX TESTING

According to the project work plan, a peer review of the beta-version of the toolbox had been planned before the individual items were finalised and prepared for further testing in the project's pilots. The peer reviews took place in July 2017. All partners who were not directly involved in the creation of individual tools were obliged to participate in the peer reviews. The peer reviews were carried out remotely as desk-based and required the participation of at least two people. The peer review itself required only a few hours of time, including the completion of a review form. For the peer review, an imaginary case example had been used, reflecting a chemical company existing in real life. When performing the peer review, one person acted as the project representative using the toolbox to give advice to the other person, who acted as a representative of the company.

After the peer reviews of beta-version of the toolbox, chemical companies and their logistics providers were invited to the pilot tests phase. Five tests on five different routes per each partner country must be completed and reported. To be able to compare the results of modal shift in terms of time, reliability, flexibility, safety, and CO2 savings, companies are asked to report data on transport chain before and after the modal shift. Pilot tests ran from October 2017 until January 2018.

4. RESULTS AND DISCUSSION

Due to the hazardous nature of the majority of its goods, the chemical industry has a priority order for different transport modes. The first priority on this list is to avoid public transport by creating large integrated production sites in chemical parks. The second-best option is the transport of chemical products via pipelines applied mainly by large chemical companies for raw materials. The third preferred transport for the chemical industry is rail transport, including multimodal transport. Rail transport offers the possibility to transport large quantities and, especially in comparison to road transport, is much safer. In-depth interviews conducted with managers from chemical and logistics companies revealed that multimodal transport is an important mode of transport for the chemical industry. The survey showed that there is a correlation between multimodal transport importance with the size and export orientation of the company. The larger the company and the higher the export orientation, the more important multimodal transport is.

However, respondents admitted that **organising multimodal transport is more challenging than a unimodal one**. When talking about barriers (disadvantages) of multimodal transport, managers were asked to evaluate them on the scale from 1 – *not important* to 5 – *very important*. The outcomes are presented in Table 3.

from logistics companies, who complained about intermodal terminals' uneven location and lack of connections with southern Europe, i.e. southern France, Balkan countries and Turkey. Respondents from both chemical and logistics companies admitted that low responsiveness to demand changes is another important obstacle which prevents them from using multimodal services.

In-depth interviews revealed that very often the biggest problem related to shifting road transport to multimodal are the **habits of transport planners who avoid multimodal freight transport planning** because they are accustomed to using road transport and they do not see multimodal transport's superiority. Besides, looking from the supply chain perspective, they see that multimodal transport requires the supply chain's reconfiguration to incorporate potential changes such as increased inventory, in particular in-transit inventory, and extended delivery windows.

Summing up, the chemical and logistics companies' managers who were interviewed understand that multimodal freight transport requires

Table 3 Barriers (disadvantages) of multimodal transport (Cichosz et al., 2016)

Barriers (disadvantages) 1 - *not important* 5 - *very important*	AVR. barrier for chemical companies	AVR. barrier for logistics companies
Lack of railway connections	4.13	4.13
Lack of intermodal terminals	4.25	3.57
Transit time	4.88	2.88
Costs	4.38	3.14
Low flexibility of transport management (low responsiveness to demand changes)	4	3.29
Extended planning and organizing	4.63	2.0
Sector's regulations	2.5	2.43

The results of the survey show that the biggest disadvantage for managers from chemical companies operating in Poland are: longer and uncertain transit time (4.88) and extended planning and organising needed for multimodal transport (4.63). Both of these arguments are directly linked to multimodal transport process complexity. Besides, managers responsible for transport in chemical companies placed costs of intermodal services very high on the list of disadvantages with the score 4.38. They pointed out in particular pricing and cost of operations in terminals as the main elements of the cost. The next two disadvantages on the list, i.e. lack of intermodal terminals (4.25) and lack of railway connections (4.13), were of the greatest importance for managers

increased collaboration between key participants, including rail operators and terminal operators. The collaboration should start at the planning stage and continue in the execution and controlling phases of the multimodal transport process.

To address the challenges and stimulate cooperation (in some cases even with elements of collaboration), the toolbox for modal shift has been developed. It consists of four elements: (1) consulting services, (2) planning guidelines, (3) IT visualisation, and (4) a CO_2 calculator (Fig. 1) and it aims at facilitating the modal shift process.

The toolbox testing stage revealed that all four elements of it are important for modal shift.

Within pre-tests of the beta-version of the toolbox, respondents evaluated every element of the toolbox on a scale of 1 – *very useful* to 5 – *not useful*. Respondents were also asked to briefly explain how they applied the certain elements of the toolbox. The survey showed that **the most appreciated element of the toolbox is the consulting service**, which constitutes a marketing platform integrating different multimodal transport's stakeholders, such as chemical producers and distributors, logistics companies, carriers, terminal operators, rail network operators, and others. Consulting services by definition are based on close cooperation, which is critical when companies share information on current transport patterns, existing potentials, and possible actions to establish and promote modal shift.

At the other end of the convenience evaluation spectrum was the CO_2 calculator. Chemical companies felt it was not useful at all as, in general, they are not interested in measuring and managing their transport emissions. This results from the fact that the transport emissions' measurement and management for chemical companies have not become obligatory yet. Moreover, during tests of the beta-version of the toolbox, chemical and logistics companies complained that the CO_2 calculator is not integrated with other transportation systems. Eventually, chemical companies considered it as a "nice-to-have" element of the toolbox, which can help in reporting emission savings. At the same time, logistics companies perceived the CO_2 calculator as a helpful tool, which could support them in convincing customers to shift chemical freight to intermodal transport, especially on routes within European transport corridors.

The planning guidelines and IT visualisation received, on average, scores between 2 and 3. Respondents appreciated the planning guidelines but complained that it was not integrated with transport management systems. The IT visualisation, provided by Intermodal Links Planner, is an easy to use platform with more than 150 partners involved in providing and updating actual data on the scheduled railway connections, intermodal terminals, and their operators, however it is also a stand-alone application. A disadvantage of the Intermodal Links Planner, highlighted by respondents, was the lack of specific information on the chemical freight handling equipment available at the intermodal terminals. Respondents admitted that this information would be received in quotation but they would appreciate to know it when selecting a multimodal route.

Summing up, the toolbox was recognised as a tool facilitating the chemical freight modal shift, which still needs some improvement but it is helpful for the first steps towards the modal shift way to more sustainable transportation.

5. CONCLUSIONS

This paper addresses the topic of facilitating the process of multimodal freight transport planning with the help of the toolbox prepared within the ChemMultimodal project. It emphasises the role of supply chain and logistics collaboration between partners within a complex modal shift planning process, characterised by the involvement of many actors operating in a diversified European environment with differentiated transport infrastructure, specific transport regulations and priorities.

The toolbox developed addresses these challenges. It makes the modal shift easier, more attractive and available, not just for big chemical players with huge volume transported over long distance, but also for medium and small players, who have to bundle their shipments with those of the other shippers to achieve a critical mass to organise an efficient and cost-competitive multimodal transport.

The toolbox is a step towards increasing the appeal of multimodal transport. With the digital revolution, and specifically the availability of information, transportation and logistics are and will be conducted more efficiently in the future. The possibility to share and exchange information in real-time with the help of e.g. Internet-of-Things, Industry 4.0, enables the integration of all modes of transport, leading to a better utilisation of the entire network through new transport services. It will stimulate cross-company transport cooperation with the flexible switches between transport modes and operators. Future research could explore these topics as well as investigate the optimisation of multimodal transport chains within synchromodal networks.

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