Facilitating synchromodal transport through interconnected, modular and intelligent transport units

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Abstract

Synchromodality has recently emerged as new transport concept that has the overall aim to create an efficient network with an optimal utilization of the available resources. One core element of this concept is the real-time switching of transport modes to foster the use of railways and inland waterways. Accordingly, the transport units deployed in the synchromodal network have to meet specific requirements, which are presented in this paper. These requirements include interconnectivity and interoperability, standardisation and modularisation as well as hyperconnected intelligence. Practical examples underline the feasibility and implementation status of the described requirements.

Keywords: synchromodality, transport unit, modal shift

Introduction

Worldwide traffic volumes have been constantly increasing and forecasts project that this trend will continue even in the future. In 2050, European freight traffic is predicted to rise by 80% compared with 2005 (European Commission, 2011). Greenhouse gas emissions will consequently rise to a critical extent. A reorganization of the current transport organization is necessary to counteract these developments. A novel transport concept called 'synchromodality' has been proposed recently to green freight transport by fostering a modal shift towards environmentally friendly modes of transport such as rail or inland waterways. In spite of being a promising new idea, synchromodality is almost unknown in most of Europe, except for the Benelux countries. In the Netherlands several successful pilot projects exist which demonstrate its viability. The best-known is the implementation of the synchromodality network between Rotterdam, Moerdijk and Tilburg (Lucassen and Dogger, 2012). Synchromodality can be seen as evolution of intermodal transport concepts. The idea of synchromodality is that switching between transport modes takes place in near real-time which allows moving goods in a highly flexible and resource-efficient way (Pfoser et al., 2016). Thus, the advantages of each transport mode can be exploited at the same time, i.e. the mass capacity nature of rail and inland waterway transportation as well as the mobility and flexibility of road transportation. This is possible since shippers are requested to book "mode free" transport services, i.e. the transport mode is not specified by the client. The forwarder is therefore able to bundle the flows of goods from different customers and optimize their carriage. Close cooperation between all actors along the transport chain allows transporting goods in a flexible and resource-efficient way (Verweij, 2011). Real-time switching also serves as a backup-system in case a transport mode is suddenly not accessible, e.g. due to changing weather conditions. To organise and control these synchromodal processes, a central network orchestrator that offers integrated transport is needed (van Riessen et al., 2015).

Accordingly, synchromodality is a transportation concept which strives to increase reliability, robustness and resilience of the transport network by introducing real-time monitoring of the transport chains and real-time mode and route choice. An important prerequisite for the successful realization of synchromodal transports is that transport units and loading systems enable the described flexible short-term switching of transport modes. Standardized transport units such as 20- and 40-feet containers have been the key of the most efficient logistics systems for decades. New logistics concepts, including synchromodality, additionally require solutions that allow increased adaptability and responsiveness. Modular transport units are capable to ensure the needed flexibility as they create interoperability between the different modes of transport (Montreuil, 2011).

In this paper we will give an overview of how transport units and loading systems can contribute to the implementation of synchromodality and therefore how they can support a modal shift. We will describe which characteristics transport units should have that would be able to facilitate synchromodal transports.

Approach

In a first step, we carried out desktop research to analyse which properties transport units should have to be appropriate for promoting synchromodal transports. The objective was to understand the implications and functioning of these properties and to be able to describe how they can support the realization of a modal shift. Figure 1 gives an overview of the detected properties, which will be later described in detail.

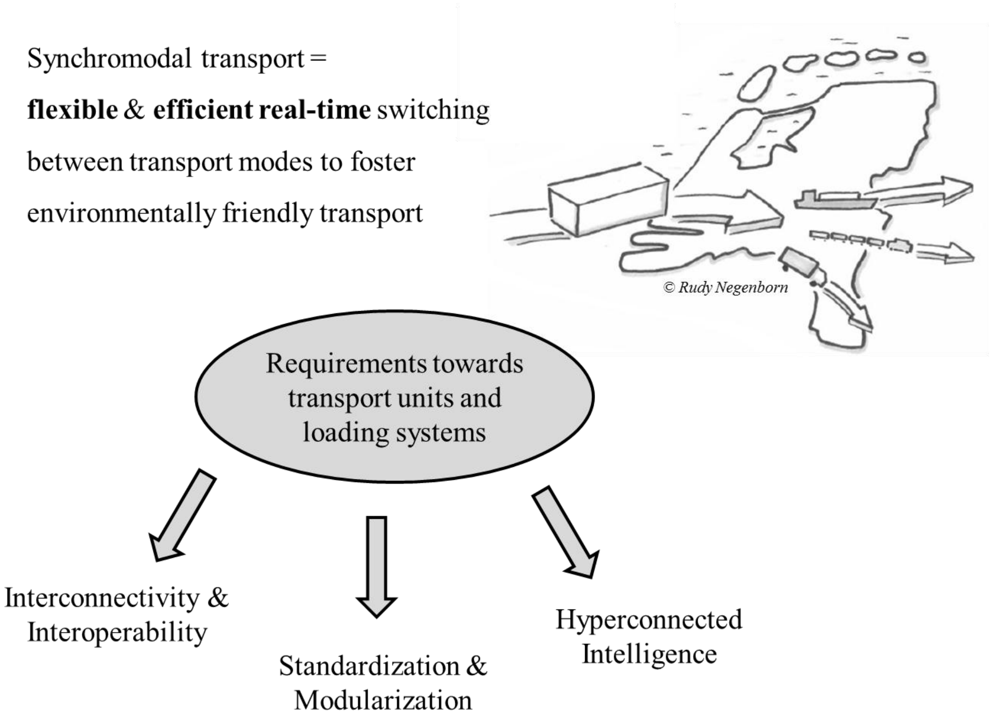


Figure 1 – Synchromodality and its requirements towards transport units

In a second step we intended to demonstrate to which extent the theoretical requirements (Figure 1) are already implemented in practice. In the recent past, various innovative solutions for transport units have been developed with the intention to make transports more efficient and intelligent or to shift freight from road to alternative transport modes. Some of these solutions have already been realized or are in a testing phase, others are just theoretical ideas under development. For this reason, we conducted desktop research to compile some state-of-the-art examples from practice. These practical insights are supposed to underline the relevance as well as the feasibility of the defined properties.

Interconnectivity and Interoperability

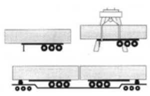
Interconnectivity is achieved when different transport modes are physically and operationally linked to facilitate transfers across the boundaries of the different modes. On the other hand, interoperability is defined as the ability of two or more transport modes operate effectively and efficiently together to fulfil the objectives of the transport network. Thus, interoperability adds the aspect of efficiency to the concept of interconnectivity (Mulley and Nelson, 1999).

The basic idea behind synchromodality is that switching between different transport modes allows to utilize the most efficient transport mode all along the whole transport chain. Environmentally friendly modes of transport such as rail or inland waterways are highly prioritized, road is only used where necessary, especially on the long haul. The ISO container is the standard transport unit used for intermodal transport. However, due to their high weight, ISO Containers are restricted in use for road transport (Solvay et al., 2016). This is why swap-bodies and semitrailers have the biggest share in road transport; 66% of road transport volume is carried by trailers. However, only 2 % of these trailers are suitable for vertical handling by cranes (Wagener, 2014). Since this is an important property for being transhipped to environmentally friendly transport modes, there is a need for solutions which make transport units craneable.

Existing literature reports on so-called “dual-mode trailer systems” (Lee et al., 2011; Kim, 2010; Lee et al., 2009). Kim (2010, p.137) defines that the dual-mode trailer system “establishes the combined transportation system through combining the road transportation and railway transportation and it is one of the methods being developed for the railway logistics technologies to load/unload the container from train without adoption of the vertical handling system.” Dual-mode trailer systems are therefore technologies aiming to facilitate intermodal handling and transportation of non-craneable semitrailers. Thus, this type of solutions is an important contribution to create the required interconnectivity and interoperability between different modes of transport.

There exist already several different concepts to empower non-craneable transport units such as semitrailers for transhipment to environmentally friendly modes of transport. It can be differentiated between solutions supporting a modal shift to rail and solutions supporting a modal shift to inland waterways. Further they can be classified into rotational systems and horizontal handling systems depending on the way how loading and unloading processes are operated (Lee et al., 2008). The following Table 1 provides an overview how these solutions can be categorized and gives practical examples for each of these types.

Table 1 – Loading solutions to create interoperability between modes of transport (Adapted from Lee et al., 2009)

				Railway solutions	**Inland waterway solutions**
	**Horizontal loading**	Requires a lower rail wagon but no unloading equipment needed	Rotational wagon	Modalohr, Cargo Speed, Megaswing, Flexiwaggon	
			Parallel loading and unloading	Cargo Beamer	
	**Vertical loading**	General wagon used but crane systems needed	Piggyback systems	NiKRASA	Danubia Kombi

The basic idea behind all of the concepts in Table 1 is to enable non-craneable trailers for being transhipped to alternative transport modes by using roll-on-roll-off solutions. There exist different approaches for that purpose. *Modalohr* belongs to the group of rotational systems. It uses specific articulated low-floor rail wagons that are designed to turn sideward so that trailers can be loaded from the sides without any equipment like reach stackers or cranes. One disadvantage is that this system is associated with considerable space requirements. Special terminals are needed for transhipment. Modalohr is already applied at certain European routes e.g. from France to Italy, but the frequency of rail connections is quite low which is another obstacle (Randelhoff, 2016). Other rotational concepts with a similar functioning include *Flexiwaggon* or *Cargo Speed.*

Cargo Beamer is a parallel loading and unloading system which works horizontally. It does not need any cranes or reach stakers but uses auxiliary horizontal movers to a road so that it can be loaded by a truck (Lee et al., 2009). The pilot trials have already been completed successfully, Cargo Beamer is technologically mature and admitted for

Europe. Since 2013 it is used along a route from Germany via Switzerland to Italy. An extension of this route is planned, but will only be possible with political support (Weinrich, 2017).

The systems *NiKRASA* and *Danubia Kombi* belong to vertical loading solutions and therefore need cranes for being transhipped. NiKRASA uses specific transport platforms that allow transhipping non-craneable semitrailers onto rail wagons. The coupled unit of trailer and transport platform can be loaded or unloaded with existing terminal equipment, thus there is no additional investment needed. Developers state that this system works easier than the conventional rolling motorway. NiKRASA is already being deployed along different routes in Europe including the combined transport terminals Herne, Padborg, Verona, Bettembourg, Malmö and Trieste (TX Logistik, s.a.). One drawback of NiKRASA is however the additional weight of the transport platforms, which is 2.5 tons per trailer. Projected onto the block train as a whole, this is a crucial factor. Similar to NiKRASA, Danubia Kombi is based on transport platforms (called "flats") onto which semitrailers, containers or even goods like new cars or machines can be loaded and which are then transhipped to a vessel. The vessels have been equipped with a specific rack system and are supposed to be operated as a regular service along the Danube (Ritsch, 2013). At the moment, the theoretical feasibility of Danubia Kombi is examined. It has to be underlined that Danubia Kombi is one of few solutions that are proposed to shift cargo to waterways. As can be seen in Table 1, many more concepts exist to facilitate intermodal rail-road transport.

Standardization and Modularization

Using standardised units entails a lot of advantages including economies of scale, reduced capital investment and cost for transfer facilities as well as a better utilization of equipment and carrying capacity (Asariotis et al., 1998). Some of the currently most efficient logistics systems are exploiting the principle of standardization by transporting cargo in the form of containers and parcels (Montreuil, 2011). Shippers perceive containers as favourable transport unit regarding ease of loading and unloading, protection of the cargo and cleanliness. When it comes to flexibility, containers are evaluated rather low because it is difficult to handle them in an intermodal transport chain (Johnston and Marshall, 1993). To provide an adequate level of flexibility, which is definitely one of the main aspirations of synchromodality, modularized transport units are needed. Modularized packaging allows addressing inefficient loading practices as they represent a possibility to reduce storage space requirements and replenishment frequencies (Norman et al., 2015).

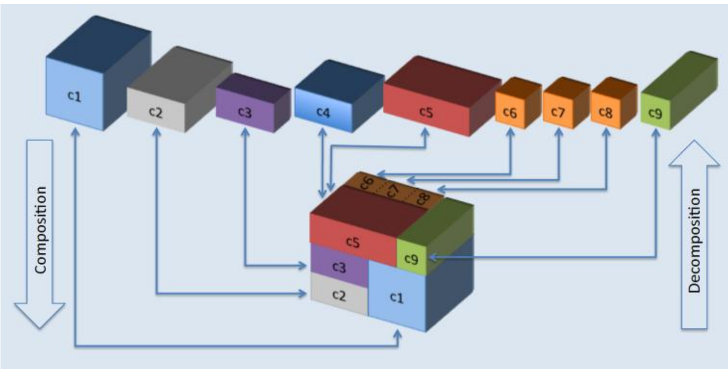


Figure 2 – Modular transport units to providing flexibility (Source: Montreuil et al., 2011)

It has to be noted though that standardisation can impede innovation and flexibility. Asariotis et al. (1998, p.6) explain that "the viability of standards in any industry is closely linked to the maturity of the industry. In more mature industries, moves toward increased uniformity are less likely to conflict with other goals." Since the synchromodal business is completely new and far from being mature, it has to be taken care that moving too quickly to standardize this concept may prevent future innovations. Thus, a sound balance between standardization and innovation has to be met to fully develop it to a mature stage.

The project *Modulushca* can be named as a practical example where standardized and modularized transport units have been developed in order to reduce the amount of empty transports and raise sustainability. The underlying purpose is to adapt the Physical Internet as vision of an open global logistics system founded on physical, digital and operational interconnectivity (Montreuil et al., 2011; Montreuil et al., 2010). Synchromodality is one of the key principles of the Physical Internet. A set of exchangeable modular transport units has been developed which provide a building block of smaller units. Thus, transport should become more efficient and intermodal operations will become easier due to overall standardisation. Current challenges faced in the project are the integration of the modular transport units into existing handling processes and to convince a critical mass of users to invest in the new transport units and associated handling and transportation assets (Landschützer et al., 2015).

Hyperconnected Intelligence

There is rising demand for the automatic identification, localization and condition monitoring of logistics objects such as transport units. The data provided by these intelligent technologies is an important source of transparency and control within a supply chain (Kirch et al., 2017). The claim for real-time optimization within a synchromodal network induces a need for intelligent transport units that have certain capabilities.

Information capabilities. Intelligent transport units have the overall aim to deliver different kinds of information. One purpose for that is to ensure identification: ideally, containers and other transport units have a unique worldwide identifier so that they can be recognised within the synchromodal network. This is also an important prerequisite to ensure traceability of the respective transport units (Sallez et al., 2016). The orchestrator of the synchromodal network must be able to locate each transport unit and provide tracking information such as status, projected arrival and departure times. This will eventually also include information about environmental conditions since synchromodality aims for a real-time response to present situations and arising incidents. Also the state of the cargo itself shall be monitored with intelligent transport units to keep track of the condition and data integrity of the cargo carried (Kirch et al., 2017). Technologies enabling the described type of requirements include for example RFID for identification purposes, real-time location systems such as GPS and temperature or humidity sensors for sensing (Uckelmann, 2008).

Communication capabilities. Communication capabilities are connected to the traceability and condition monitoring needs as they ensure an adequate provision and use of the collected information. Also the Physical Internet containers (e.g. Modulushca, see above) are supposed to use long and shortrange communication technologies such as Zigbee, EnOcean or LoRaWAN (Long Range Wide-area network). Transport units should not only communicate with the synchromodal orchestrator, but also with each other to check compatibility and mutual objectives in transportation and storage (Sallez et al., 2016).

Decision capabilities. Since real-time decision making is required in a synchromodal network, intelligent transport units are in the ideal case capable to make some of the decisions autonomously such as the final choice of the most efficient transport route which should be optimized based on present circumstances. This could also include decisions about optimized handling and sorting in the logistics hubs (Sallez et al., 2016).

It must be noted that confidentiality issues might arise due to the information provided by an intelligent transport unit. It is important that only authorised users have access to the available data, especially when it comes to the content of the handled and transported package. This is a critical enabler for synchromodality as confidentiality is a key factor for successful cooperation between companies (Leitner et al., 2011). Data encryption and enhanced dynamic right management are instruments to establish appropriate confidentiality (Montreuil et al., 2010).

The futuristic requirements described above have already been realized by the technology provider *TRAXENS*. This company has developed tags that transform transport units into intelligent objects able to communicate with each other and with transport hubs. TRAXENS can provide real-time information about all planned and exceptional events that happen during the shipment. The monitoring device does not only provide data about the location of the transport unit, but also about environmental conditions. Sensors measure temperature, humidity, and amount of carbon dioxide inside a container; when and where the doors of the container have been opened; and whether the container has been subjected to unusual shocks or vibrations (Dupin, 2016).

Conclusion

The expressions *intelligent* or *smart* have become buzzwords to describe most recent developments which are often connected with digitalization and innovation. Intelligent logistics can be described as “different logistics operations (inventory, transport or order management) which are planned, managed or controlled in a more intelligent way compared to conventional solutions” (McFarlane et al., 2016, p. 106). With the flexible and optimized real-time switching between transport modes, synchromodality can be considered as such an approach aiming to improve logistics systems by making them more intelligent. Consequently, also the deployed transport units have to meet certain criteria which have been described in this paper.

The increasing amount of international trade due to globalization causes relevant efforts within the transport sector. Among transport activities, transhipment processes account for an increasing share, and this development is predicted to continue even in the future (Zhen et al. 2011). It is therefore highly important that transhipment activities are executed as efficient as possible. However, transport units are in many cases not suited for being handled by cranes. Desk research has shown that there already exist a relevant number of cargo loading systems that have been developed as solutions for this problem. Since the majority of trailers used in road traffic are non-craneable, concepts have been developed to enable these trailers for being transhipped to environmentally friendly modes of transport such as rail or inland waterways, which is an important feature of synchromodality. It has been demonstrated however that there are many more solutions for shifting to railways than to waterways.

A standardisation of transport units is also important to ensure consistent handling surfaces and reduce costs for loading and unloading. This is a crucial issue since a synchromodal network might provoke a higher number of transhipments due to the modal shift ambitions. A modularization of transport units promotes flexibility and may facilitate a better utilization. Since the bundling of shipments is highly encouraged in a synchromodal network, standardization and modularization are also practical properties that should be achieved.

Finally, the real-time aspirations of synchromodality require intelligent technology that makes transport units smart and hyperconnected to each other and their environment. To respond immediately to incidents in the supply chain and to enable real-time switching, sensors are the appropriate equipment to monitor current conditions of the transport.

The practical examples that have been presented in this paper demonstrate that the requirements related to transport units in a synchromodal network are actually feasible and realisable. At the moment, many different systems and concepts are proposed to establish the preconditions for synchromodality. Not all of these solutions will find widespread implementation; time will tell which of them are the most viable and will emerge as standards.

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