Shared Transport Systems—A New Chance for Intermodal Freight Transport?

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Abstract The term intermodal transport subsumes transport processes in which the carried goods are packed/stored in loading units like containers or swap bodies or trucks or trailers and these loading units are moved by truck in the local area distribution and collection as well as by train (or barge) during the main-haul process phase. In this paper, we are going to investigate the hypothesis that the reformation of the management and administration of intermodal transport chains can contribute to the promotion of this environmental-friendly and highway-disburdening kind of long distance freight transport. We propose to change the administration, and to manage a combined transport chain as a so-called shared system. The primary goal of the here reported research is to analyze the general applicability of the sharing principle in intermodal freight transport.

Keywords Multimodal transport · Intermodal transport · Shared transport system · Resources · Combined transport

Introduction and Motivation

At least two means of transport (road, rail, see or air) are combined in one transport chain in *multimodal transport* (Heiserich et al. 2011) for fulfilling a single origin to destination transport process. The term *intermodal transport* addresses transport processes in which the carried goods are encapsulated in loading units like containers or swap bodies or trucks or trailers (Kummer 2006). These loading units are transshipped between different types of means of transport during the execution of the multimodal transport process, but the goods contained in the loading units remain within their original loading unit throughout the complete transport chain.

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In multimodal transport processes, handling activities (loading, transshipment) and transport activities are alternating. The primary motivation for setting up multimodal (intermodal) transport chains is obvious: combining the strengths of each involved transport means in order to overcome the weakness of single-mode transport chains.

The combination of truck-based road haulage and cargo train service in a transport chain is the most prominent realization of an intermodal transport chain (UIC 2012) in Europe. Here, the truck's ability to reach almost every place in a region is combined with the train's ability to travel at relative high speed and in an independent track. Furthermore, more than 6.7 millions of tons of CO_2 can be saved annually if trains are used for bridging long distances (UIC 2012). In an intermodal transport chain, the collection of the load in the origin region is assigned to a truck service. Transshipment from the truck to the train of a container, of a trailer, or of the complete truck is executed at a dedicated intermodal terminal in an early phase of the transport chain in the origin region. Transshipment from rail to road is performed in the destination region, so that the last phase of the transport chain is again executed by truck on the road. Such a setting is called combined transport ("Kombinierter Verkehr") or CT.

Several governmental programs have been setup to promote CT and to define incentive schemes with the goal to achieve a gain in the modal split for train transport (Kombiverkehr 2013): (i) tax reductions for trucks involved in CT chains apply, (ii) an increased maximal allowed total vehicle weight, and (iii) relaxation from driving prohibitions on weekends and during holiday for trucks involved in the execution of a CT process.

Several technical innovations for easing and accelerating the transshipment of loading units from trucks to trains and vice versa have been proposed and tested in prototypes like CargoBeamer (CargoBeamer 2013), Modalohr (Modalohr 2013), MegaSwing (Randelhoff 2012), Flexiwaggon (Randelhoff 2011).

Despite tremendous efforts to promote CT in Europe and despite an average annual growth of approximately 7 % (UIC 2012) its contribution to the total transport performance is quite low. CT accounts for approximately 44.711 million tkm (Burkhardt 2012) of 3.824.000 million tkm (Eurostat 2013) in 2011 which is a share of approximately 1.1 %. The setup and operation of CT chains seem to be unattractive under the current legal and economic conditions, and the incentives schemes installed for promoting CT seem to be inappropriate.

In this article, we are going to analyze the hypothesis that the reformation of the management and administration of CT chains has the potential to lift the contribution of this environmental-friendly and highway-disburdening kind of long distance mode of transport. For this reason, we propose to change the administration and to manage a CT chain as a so-called *shared system*. This approach of organization is currently applied successful to passenger transportation as bike-sharing (Ricker et al. 2012) as well as car-sharing (Ciari and Balmer 2008) and it is based on the principle of *using instead of owning* (Deffner and Götz 2013) that is in line with the idea of a *shareconomy* (Weitzman 1984) in which risks and benefits are shared among all market participants. In order to validate the aforementioned hypothesis, we first develop a catalog of criteria that covers customer requirements concerning CT operations. Next, we propose four generic transport system setups ranging from private to shared systems. We use the catalog of criteria to evaluate all four setups. We will demonstrate that shared systems outperform the other transport system organizations concerning customer satisfaction.

The primary goals of the here reported research are (i) to check if shared transport systems match (in theory) the requirements of CT and (ii) to identify structural similarities and commonalities between already existing shared systems and to identify discrepancies between the requirements of long distance freight transport (especially using CT) and abilities of today's shared systems.

The second section of this article summarizes the major weakness of today's CT systems. The third section compares structural properties of shared transport systems with the structural properties of traditionally operated and administrated transport systems. The fourth section discusses the opportunities and challenges for the installation of a shared system in combined freight transport.

Transport Systems Combing Road and Rail

Although, CT covers also integrations of maritime long haul transport with road-based collection and distribution services, we here focus on the combination of long haul train-transport services with truck-based short distance road services in the collection and distribution phase of a freight transport chain. Here, two modes of CT are distinguished: a complete truck (tractor and trailer in one piece) is loaded on a special wagon in the piggyback mode (accompanied CT), but in the so-called container mode only a non-motorized semi-trailer or swap-body is loaded on the train at a transshipment terminal (unaccompanied). While piggyback services are installed especially in short-distance services on dedicated relations (UIC 2012), the second mentioned container mode is used primarily in the long distance freight transport. The here reported research focus on CT in the unaccompanied mode which realizes more than 95 % of the CT services (UIC 2012) in Europe.

Road Haulage Versus CT: Comparing Demand

It is impossible to execute a fair comparison of costs for a pure road transport with a CT service. Since there are differences in the departing times of a train, it would be necessary to determine costs for a later arrival of the shipment if a part of the distance is bridged by a train and so on. Furthermore, different durations of the total transport have to be compared as well as reliability related issues (congestions on the road vs. disturbances on the rail tracks or during transshipment). Although it is hardly possible to determine mode-specific costs (for pure road transport as well as in CT) for a specific transport demand, there are empirical data to be evaluated for a rough comparison of the two transport modes. The following data from several sources are summarized in Gefeller (2012).

At first, the costs per km on the road are declared to be 1.14 EUR in road haulage compared to 1.15 EUR for a km in CT. If the total transport distance is larger than 300 km (domestic traffic) or 500 km (cross border traffic), then the CT becomes cheaper than the transport exclusively executed by truck. 60.4 % of the CT performance is realized in domestic services in European countries (UIC 2012), i.e., bridging distances around 500–800 km.

With respect to the transport duration, it is calculated on a theoretical base that a least transport distance of approximately 350 km is necessary to enable CT to outperform the road transport. This is mainly caused by the legal limitation of the driver's working hours declaring that a break must be made after 4.5 hours of driving. This working break consumed the time advantage of the truck caused by the duration of transshipment in CT.

The chance of delay in CT chains is twice as high as the delay probability of road-based transport.

In order to inform the shipper on the progress of the transport process execution, tracking and tracing systems have been developed. While 70 % of road-based transport is covered by these systems, only 15 % of all CT services can be surveyed by the shippers.

According to the aforementioned statements, CT services seem to offer benefits in costs and speed if the overall distance to be bridged is sufficiently long. However, the punctuality as well as the transparency of CT services compromise the quality of this mode of transport.

Barriers of International Rail Transport

Benefits from CT services can be gained, if the transport distance to be bridged is sufficiently long as discussed just above. However, transport services of these long distances are of the international transports and the national borders are crossed during the main-haul process phase executed on rail. Cross-border rail transport is typically slower compared to the domestic rail transport. Beside technical reasons (different widths of tracks or different power systems requiring technical reconfigurations of a train) especially organization issues slow down the average speed (Gefeller 2012). Often, it is necessary to change the conductor close to the border in order to satisfy specific national laws and operation rules. Furthermore, the national train control systems do not interoperate so that a train waiting to enter the rail system of another nation must be inserted manually into the control systems. Uncoordinated interfaces between national track systems are mainly responsible for these delays.

Managerial Deficiencies

In the early beginning of CT operations in Europe, there was the so-called CT operator business model (UIC 2012). The CT-operator was responsible for providing, organizing, and selling CT transport capacities. It does not operate own rolling stock or trucks.

Today, CT operators often integrate own assets in the CT services (logistics service provider in operator role) as claimed in UIC (2012). There is often no clear separation between the provision of rail service capacities that can be involved in CT services, and the usage/access to these resources. If the provision of rail service resources as well as the decision about the allocation of these resources is made by a forwarder then there is the danger of biased access granting decisions. An independent road haulage company that is searching for rail service resources to realize a CT service process might be excluded from these services by the aforementioned company, because it hopes to get a competitive advantage by excluding its competitor(s). Furthermore, the quasi-private provision of rail services contributes to keeping the total resource availability for rail services intransparent. Again, an external road haulage company is obstructed to get information about available resources of the rail services which makes it less obvious that available rail service capacities will be sold.

Often, rail service companies are organizing CT services, but their services are mainly oriented on the needs and requirements of their core business (operating rolling stock) but the specific needs of CT are ignored, e.g., temporal coordination at terminals, etc., is missing. The frequency of train services is quite low; often there is only one train departure per day scheduled for a destination. A short disruption in the collection and forward feeding phase on the road might lead to a delay of more than one day if the train connection is missed (Gefeller 2012). The chance for a delay in CT is quite higher than in pure road transport. It is necessary to offer a bigger portfolio of train services.

In summary, the primary management tasks in CT are to govern the interface between rail and road transport and to provide sufficient rail service capacity. It seems to be a good idea to separate the provision of rail service capacity from the operative allocation decisions because (i) the trust in such a rail service resource management will increase and (ii) the specialization in buying and selling rail services contribute to overcome some of the aforementioned problems related to the provision of a suitable high capacity of rail services that can be used in a more flexible manner. Such a form of organizing CT services is closely related to the original CT business model, which was the CT operator mentioned at the beginning of this subsection.

Desired Properties of a CT System

It is a vital prerequisite that the development and extension of CT services must be supported by the government as part of transportation policies. A clear statement about the desire to promote this mode of freight transport is necessary, but also effective incentive schemes (coded in specific laws and decrees) must be preserved or extended. However, the most important aspect in the promotion and innovation of CT services is the establishment of a clearly structured and elaborated business model for the management of CT services. Considering general requirements specified for an effective and efficient transport system together with the specific requirements from CT discussed just above, the needs and desires of potential users of combined short distance road/long distance rail transport services can be described more specifically. (i) it is necessary to offer the transport services to a **large number of customers** (ii) for a single customer an **easy and uncomplicated access** to the offered CT services is desired (iii) if there are CT services then these services **are offered to all customers** who need CT services (iv) customers are expecting the fulfillment of their demand, e.g., the **expected availability of service** is high (v) customers require **comprehensive and transparent information about the available services** in order to find out the service, best tailored to the requirements of a specific demand (vi) l**ow transaction costs** for booking and using a CT service are expected (vii) a **transparent tariff** for the determination of the service fees is needed (viii) a **strict and clear separation between the responsibilities for the provision of rail services, and the decision about the dispatching** of those services is necessary as discussed above.

Classification of Generic Transport System Setups

There are a lot of different engineering innovations offering cheap and quick transshipments (cf. introductory section). For this reason, we assume that the major obstacles for establishing a well-performing and accepted CT system are caused by an unsuitable management and setup of a CT system. This issue is investigated within the remainder of this section. We first present four general concepts (“phenotypes”) for setting up and controlling a transport system. Afterwards, we analyze these four generic management schemes with respect to the desired system properties outlined at the end of the previous section.

Phenotypes of Transport Systems

Each transport system management has to integrate and coordinate at least three involved groups. The **owners** (shareholders) of the system are primarily responsible

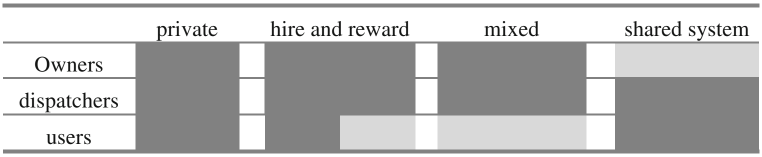

Fig. 1 Coalitions and relationship in the four generic transport system concepts

for providing and funding resources and making strategic design and capacity decisions. The **users** of the transport system specify the explicit demand and pay for the system usage. The **dispatchers** of the system are primarily responsible for the handling of transport demand and the deployment of resources. They control access to the resources of the transport system.

Depending of the intensity of interaction and cooperation among these groups, we can identify four generic setups of the administration and control of a transport system. Figure 1 compares these four setups in light of the relations among the three groups. For each setup, dark grayed groups are in close relationship providing coalitions and interactions in the provision and usage of resources.

If there are quite strong organizational and/or legal relationships among all three groups, then the transport system is called **private**. A private transport system is inaccessible for external users, but it serves only internal users. An example are so-called "own-account" transport systems setup and operated to realize transportation between different locations of a company typically with own or exclusively hired transport equipment.

In a **hire-and-reward (or carrier)** transport system, the owners and the dispatchers strongly collaborate, but the users are independent from both. This is all users are external users. They have to pay for the utilization of resources of the transport system. It is referred to road haulage companies as a representative example for a pure carrier network.

A transport system is called a **mixed-mode transport system** in case that owners and dispatchers are closely coupled, but if both internal as well as external users are served. Often, private transport systems offer residual capacity on the spot-market besides fulfilling longer term contracts.

Private transport systems are inaccessible to those who need transport services, but who are not in possession of the privilege to be an internal user. The two remaining concepts (hire and reward as well as mixed) are based on the idea to own specialized resources and to make profit by granting paid access to those, who need these resources. In order to maximize the total profit from the utilization of scarce transport resources, access to these resources is strictly controlled. Access is granted only to the most beneficiary demand according to the realized profit. Consequently, transport resource capacities are kept as scarce as possible leading to "artificial bottlenecks."

In order to avoid artificial bottlenecks and with the goal to offer transport opportunities to all users, so-called **shared mobility systems** are setup. Such a transport system is setup following the idea of "using instead of owning" (Deffner and Götz 2013). Here, the primary goal of setting up a transport system is to fulfill almost all demand for transport for a variety of customers like in bike- or car-sharing systems.

Analysis and Comparison of Organization and Access

Table 1 summarizes the major findings of the comparison of the four generic organization approaches for transport systems as a result of the analysis of representatives for the four generic transport system setups. Those attribute values that are important for the acceptance and usability of an intermodal transport system combining road and rail services are underlined. With respect to the number of fulfilled attributes, the concept of a shared transport system outperforms all other generic forms of organizing and administrating a transport system. However, managing a shared transport system requires a preregistration of later users in order to enable the provision of sufficient transport capacity that is large enough to serve the upcoming transport demand without the necessity to reject customer demand due to exhausted capacity.

Table 1 Evaluation results of the comparison of the four generic transport system concepts

	Private	Hire and reward	Mixed	Shared system
Access rights	Internal	External	Internal and external	Internal
Access control	Only to internal users	Profitability of demand	Profitability of demand	Only validated users
Management goal	Serving all demand	Serving only profitable demand	Generate margin contribution from external demand	Serving all demand
Expected resource availability	High	High	Moderate	High
Availability of information about free resources	After explicit demand specification	After explicit demand specification	After explicit demand formulation	Survey on all available resources
Transaction costs	Low	High	High/low	Low
Cost calculation	–	Transparent	Intransparent	Transparent
Separated responsibilities	No	Yes	No	Yes

Shared Mobility Systems for Freight—Challenges and Benefits

Shared transport systems are established in order to offer transport capacities and opportunities to serve individual transport demand whenever needed, but to free a user from the obligations related to the ownership of a transport resource. The primary goal of the management of a shared transport system is to serve all incoming demand independently of the achievable revenues. It is a distinguishing mark of a shared transport system to offer a clear and transparent fee calculation scheme and to inform all users about all available resources.

Existing Shared Transport Systems

Shared passenger transport systems are realized for bikes and cars in a lot of big cities around the world. Here, the shared transport system is established in order to supplement schedule-based public transport systems. Bike-sharing systems are established in urban regions where it is impossible or undesirable to use private cars or taxis due to congested streets or well-extended pedestrian areas or elaborated public transport systems. A system of rental and return stations is spread over the covered region. A customer must be registered before he/she can rent a bike. Especially, he/she has to agree to the rules of usage and the utilization tariff. Each registered user, who has a demand can go to a renting station, identifies himself/herself there and then the user gets a bike. After the user has finished the bike ride, the bike is returned at the renting or any other station where the returned bike is locked again. This bike can now be used by another user. Since pickups and returns of bikes can be done only at the designated stations such a modus operandi is called **station-based shared transport system**. There are also **station-less bike-sharing systems,** where rented bikes can be left locked, e.g., at any corner of two roads so that also one-way trips can be realized with a rented bike. Available bikes are located using modern information technologies. Rents are started and terminated also by data interchange with a service center via modern communication devices like smartphones.

Car-sharing systems offer vehicles to those people who do not own a private car, but who need a car from time to time. Car-sharing is more flexible than scheduled public transport services. Compared to traditional car rental car-sharing offers a more flexible and cheaper way to get access to a car. However, the number of available types of cars is low in car-sharing systems. After the car ride has been completed the rented car must be driven back to the car-sharing station where the next user will pick up the car. In general, the car has to be given back at the station where the current ride has been started. In few systems it is possible to return the car at another station (station-based shared transport system). Recently, first attempt are made to established station-less car-sharing systems.

In all setups bike or car-sharing systems cover only a certain region like a city or a greater area around a city. For long distance rides (especially one-way rides) it is necessary to rent a car from a car rental company.

Although the idea of “sharing” transport resources with others is known in freight transport systems, no shared transport system is reported. In freight transport, the term sharing mainly refers to situations in which independent companies help each other in the fulfillment of requests. In a groupage system (Kopfer and Pankratz 1999) available capacities are announced to all groupage system members but the final decision about the resource allocation is left to the resource owner. In other situations several shippers and/or carriers form a joint venture in order to benefit from balanced high capacity utilization. However, such a system does not fulfill the properties of a shared transport system as discussed before since only few customers are granted unlimited access to the transport resources.

In the remainder of this paper, we compare structural commonalities and discrepancies of combined freight transport systems with the exhibited properties of successfully established shared passenger transport systems.

Structural Commonalities with Already Existing Shared Systems

In passenger transportation, shared systems have been established as an alternative mode of transport in local areas. They offer an extended flexibility compared to public transport services (representing a hire-and-reward transport system configuration), but it becomes unnecessary to own a car (representing the “private transport system”) if such is car is not needed frequently.

Both bike-sharing as well as some car-sharing systems offer the one-way utilization of the resources. Such an opportunity is also required and needed in freight transportation with combined rail and road services in one-way-rail-services. However, as in bike- and car-sharing systems, repositioning activities of unused resources (Ricker et al. 2012) must be established in order to provide the empty capacities in rail services (the rolling stock) at those places where loading units want to board a train service.

The available vehicles and/or bikes can be found by a user by consulting an information system using sophisticated communication systems. That is, the transparency of available resources is quite high. This transparency is also needed in combined freight transport systems as discussed above.

There are only few or there is even one type of resource available in a car- or bike-sharing system. In consequence, one or only few resource types must be differentiated in the transport system. This fact contributes to a sufficient management of the resource availabilities at the different system access points (ride start points). In general, only one type or at most few types of railway wagon is/are needed in combined freight transport system for carrying trailers, swap-bodies or containers.

Finally, the organization of a bike- or car-sharing system is based on an elaborated management of the resource capacity. The installation of rental and return stations as well as the provision and maintenance of the cars and bikes but also the necessary repositioning of bikes and cars is in the responsibility of a company who has no own need to use these resources. Furthermore, all users contribute to the covering of (at least a part of) the costs for running and maintaining the shared transport system. Therefore, it can be assumed that all users are treated equal and in a fair manner. Such a form of organization is required in combined freight transport in order to overcome the critical resource provision and availability deficiencies and shortcomings.

Distinct Structures and Challenges

Although, we have identified several structural commonalities of the needs of shared CT systems with existing shared passenger transport systems, we are also aware of at least two significant structural distinctions.

First, the spatial extend of the network is significantly increased in intermodal freight transportation compared to passenger transportation systems in which bike-sharing and/or car-sharing systems are successfully operated. That is, longer distances have to be bridged and the repositioning of rolling stock requires a more sophisticated organization since the repositioning times are longer, more uncertain, and more expensive.

Second, railway operations are quite more complicated than transport operations in the road network. The right to use a track has to be announced toward the infrastructure provider before the operation is scheduled. The own rolling stock operations must be synchronized with the pre-booked infrastructure access and finally, international rail operations require the solving of several complicated organizational challenges as mentioned above.

Conclusion

Our initially stated research hypothesis has been validated. The organization of a CT as a shared transport system has the potential to improve the fulfillment quality and reliability of customer service requirements. The concept of a shared transport system seems to outperform other more traditional forms for organizing a CT network. We have revealed some important structural discrepancies between shared passenger transport systems, and the needs of shared freight transport systems especially in CT integrating rail and road operations. Nevertheless, a lot of structural commonalities between these two application fields have been discovered.

In a next research step, it is necessary to propose a business model for a shared freight transport system for CT. One idea involves the reanimation of the CT operator business model that has been used when CT was established. However, the funding of such an operator company must come from the whole set of prospective users in form of a type of membership. Only members are allowed to use the commonly provided rolling stock resources, but each member can organize upstream and downstream operation on the road with own resources for own account.

It is necessary to install a comprehensive resource availability information system. Furthermore, a transparent fee system has to be setup that covers the costs for running the shared railway operation system. If these costs are "too high" than there is no market for CT, and it is impossible to offer the required services at acceptable prices. In this situation, governmental extra funding or incentives are needed. However, the recipients of the extra funding are known: those companies, how are responsible for setting up and running the rolling stock and operating the transshipment terminals. In this situation, the target-oriented utilization of the additional funding is obvious since the company's only goal is to operate the needed rail services and terminals. Misuse of the extra funding is more or less impossible and the effectiveness of the funding can be controlled easily.

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