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INTEGRATING RAILWAY SERVICES INTO THE SUPPLY CHAIN AT THE LAST MILE OF THE TRANSSHIPMENT INTERFACE SEAPORT-RAIL

Abstract: The paper considers the transhipment process between sea ships and railways as a critical hinge where goods are moved from one transport mode to another one. By linking them, a transport chain is created. During research it has been found out that processes between the intermediaries of the transport chain seaport–rail are not well organised and adjusted.
A low level of communication between the intermediaries (ports, freight forwarders, railway transport companies, etc.) leads to conflicts and insecurities in rail freight transport. Additional time buffers which are planned by railway companies and freight forwarders due to those insecurities in the transport flow make it slow and untimely. That makes it difficult for the intermediaries to plan own activities in an optimal way.
The untimely trains and the non-adjusted railway transhipment works in ports, makes the transport processes longer than they need to be. With a better integration of the operational processes the transport chain shall be better adjusted.
In this paper the actors as well as the processes at the interface seaport-rail have been identified and characterised. The interrelations between single transhipment processes have been examined but also the way how they are integrated in transport chains.
In a first research a sample of observed 50 freight trains has been chosen to evaluate the integration of rail freight services in transport chains. For the trains, their involvement in certain processes within a seaport's rail yard has been quantified. It was possible to distinguish between their involvement in productive and non-productive processes and thus have been identified.
The results of the field research lead to the development of an information flow model which is aimed to reduce buffer time by enabling a better communication between the intermediaries of the transport chain. Approaches for further research to link the partial works of single intermediaries in an organisational and applied way are presented. With it, the insecurities during the transhipment within rail freight yards in seaport shall be reduced. Thus, additional time buffers can be minimised and the ship–to–rail transhipment flow becomes smoother.
Keywords: supply chain, integration, railways, rail freight, rail cargo, seaport, terminal

1. THE INTERFACE SEAPORT-RAIL

At the interface between two logistic subsystems, goods as well as information have to pass through barriers. To achieve a fast and smooth transfer from one subsystem to another, it is necessary to establish links. By linking two or more subsystems, a transport chain is created. The linkage between two logistic subsystems is permitted by interfaces. The efficiency of those interfaces has a wide influence on the efficiency of the whole transport chain and also on the competitiveness of the used transport modes.

An important interface between transport modes is the one between sea ships and freight trains. It is crucial for international and intercontinental freight transports but also for combined transport. More precisely, it is a connector for commodity flows between continents in the main run and the pre and onward carriage to serve inland destinations. Within the pre and onward carriages railways play an important role, especially for long-running services. A noteworthy modal split is reached amongst others for services from and to the ports of Hamburg (32%), Bremen (35%) and Zeebrügge (31%) (see [1]).

Railway facilities in ports and freight terminals have a limited capacity to perform necessary logistic processes. In addition, several actors are involved to perform transhipment processes. Both facts have an impact to the quality of the transport chain. The challenge to face is the spatiotemporal linkage of all the involved actors with the minimisation of infrastructure utilisation to achieve a high integration of the transport chain. Therefore the actors and the transport processes have been identified in detail as shown in the subsequent sections.

1.1. Actors at the interface seaport-rail

A number of actors are involved in the transhipment processes needed for a transfer of goods from the sea ship to a rail car. Their organisational interdependences and the necessary flows of information and goods between them are shown in

Figure **1** for the case of import flows (directed from seaport to inland destinations). For export flows the figure is to be seen vice versa. The Forwarder acts the role of the organiser which is authorised by a customer to perform the transport process. He instructs a set of executing actors to fulfil the transport process:

- shipping company / ocean carrier,
- port authority,
- at least one train operating company (TOC),
- one or more railway infrastructure managers (IM) and
- additional transhipment terminals or points of reception

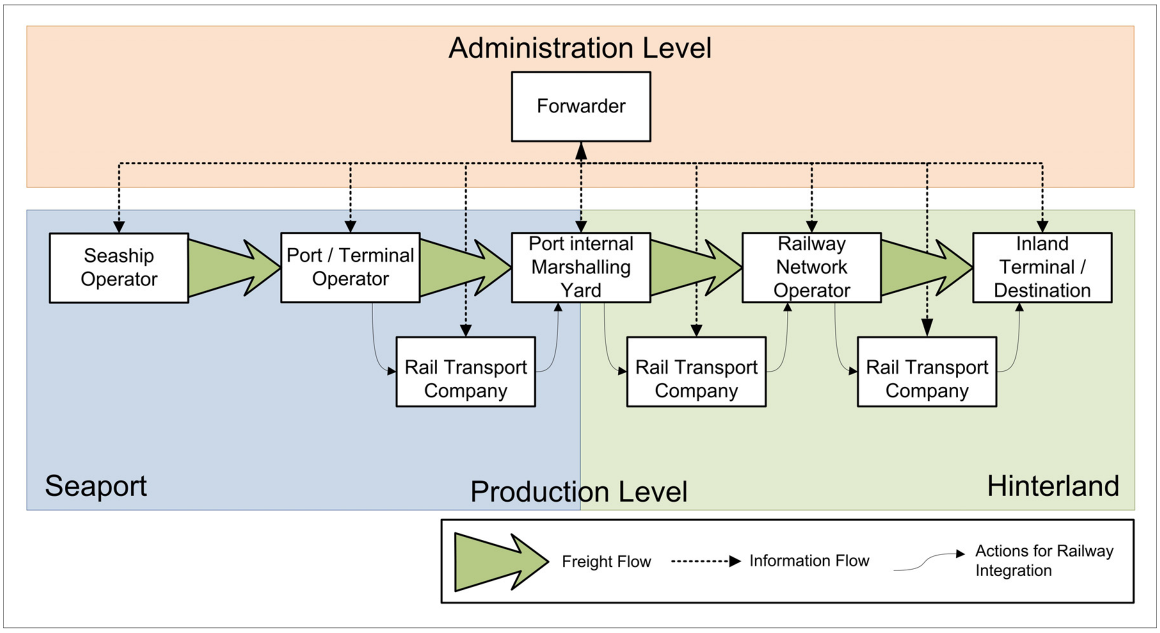

Figure 1. Actors involved in transhipment processes at the interface seaport-rail

The processes shown in this figure are part of a transport chain that begins generally before the seaport and ends generally behind the inland terminal. Since the focus is on the interface between sea ships and railways the remaining processes are hidden.

1.2. Transport processes at the interface seaport-rail

A number of activities are needed to transfers goods from a sea ship onto a rail freight car. Thereby it is to distinguish between pure logistic activities and railway operational activities. Logistic activities describe processes where the handled good is affected directly, such as:

- customs control,
- warehousing / storage,
- turnovers to load and unload goods

By contrast, the railway operational activities describe processes which do not affect the good itself:

- shunting of wagons and trains,
- coupling and sorting of wagons to form trains,
- brake tests for trains and further railway operational procedures

Each process is handled by one or more actors. One actor can be involved in several processes. An efficient succession of processes requires a constant exchange of information between the actors of two processes. The linkage between the actors connects single transhipment processes to a whole, decreases turnover times and reduces capacity losses.

2. THE CHARACTERISTICS OF THE LAST MILE IN RAIL FREIGHT TERMINALS

2.1. Disparities in transhipment performance

The logistic activities in seaports are preferably orientated on a fast loading and unloading of the big container ships to reduce their holding time (an idle period). The crucial factor is the capital employed during transport. With the increasing vessel size the handling capacity increased, too. Modern container cranes in seaports are able to perform around 30 handling operations per hour whereas generally more than one crane is used to load or unload a vessel. Using triple spreaders, up to 95 TEU per hour can be handled as it has been estimated in [2].

The handling capacity to serve rail freight cars, using mainly gantry cranes with around 20 operations per hour, is considerably lower. Those disparities require storage facilities as a buffer. A direct transhipment of goods from sea ships to rail wagons would imply a very short handling time for a single item but would also lead to a collapse of the handling capacity at the quayside. Storage facilities for goods in seaport areas, thus, can be minimised but not withdrawn.

2.2. Sorting and transhipment tasks

A rail freight terminal is a place to collect and to distribute goods. Goods from several inland destinations are concentrated in storage areas of seaports for export. Also, imported goods will be distributed among inland destinations. Consequently, a seaport is destined to sort goods for delivery to a set of hinterland destinations in import direction and for a set of vessels in export direction respectively.

Regarding the interface seaport-rail, the sorting is arranged in the terminal area directly (goods are not loaded to wagon) as well as in following marshalling yards (goods are loaded on wagon). The direct sorting in terminals is a pure logistic process and organised by the terminal. In the last years much research already has been done to optimise the work flow in terminals. On the contrary, the sorting and shunting of wagons is rather an operational issue which should be examined more precisely.

Before the operational issues are explained more precisely, the rotation of freight wagons in endpoints shall be explored generally. Figure 2 shows the single stations which a freight wagon has to pass in an endpoint as a scheme.

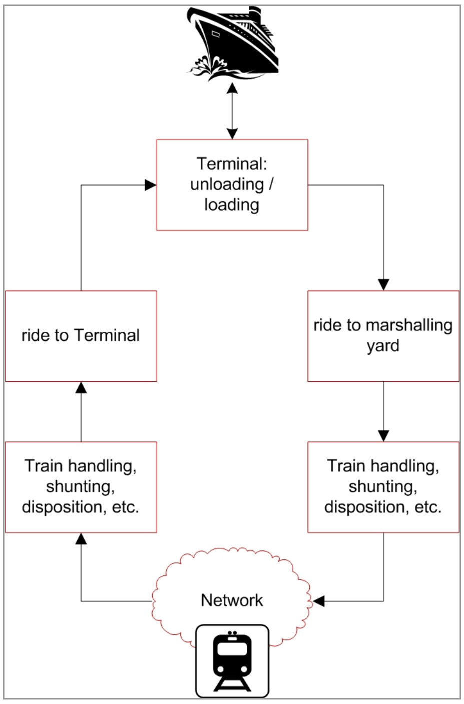

Figure 2. Rotation of freight wagons through stations in endpoints such as cargo terminals and seaports.

Starting from the bottom of the figure, a wagon coming from the railway network enters the port area as part of a train. Since not all wagons will go to the same terminal track, a process of shunting and sorting is needed. Exceptions are block trains which are generally not divided and operate as a whole. The shunting and sorting processes are known to be time consuming and thus they make rail freight services unattractive and expensive. After the loading process, the wagon returns to the marshalling yard where shunting and sorting processes might be required again before it goes back to the network. The rotation scheme is of course idealised. In reality it happens regularly that a wagon is shunted more often before it leaves the seaport area. This is due to little optimisation of the railway operational steps.

2.3. Coordination in rail freight terminals

Usually, the coordination of the port-internal wagon flows is based on time slots provided by the terminals for each loading siding. Sets of time slots can be understood as a schedule to determine in which time period a certain terminal track is reserved for certain transhipment procedures. Logistic service providers who got a time slot have to plan suitable wagons to be available in the marshalling yard before the slot time starts. Also, a shunting operator with its locomotive must be available to transfer the accordant wagons to the loading sidings.

It becomes apparent that the process of wagon provision is already very complex and several actors are involved in it. In small freight terminals with only one operator the issue is straightforward and can be solved with little effort. Bigger freight yards, where several logistic service providers, several marshalling operators and possibly several terminals compete against each other, are confronted with a complex problem which is not easy to solve.

Returning back from the loading sidings, the sequence of procedures is similar: Shunting and sorting operations as well as the formation of full trains with certain railway operational requirements has to be done timely to catch the network track access slot which has been booked in advance at the railway infrastructure manager.

Summing up, it is to mention that the wagon flows in rail freight terminals are coordinated in two directions whereas in both cases the last process is the critical one. In addition, in- and outgoing flows are to be connected to achieve an optimal wagon capacity utilisation and to avoid empty running.

3. SUPPLY CHAINS AND RAILWAY SERVICES

Section 2 illustrated that the interaction between the single processes in rail freight terminals and the actors involved is very complex. While a lot of research regarding the optimisation of transhipment operations in ports has been done, only some research focuses on the transport integration; see for example [3] and [4]. Other studies concentrate on the coordination of the hinterland transport chain as a whole, like [5]. Own research, examining especially the landside part of the interface between sea ships and railways, pointed out that there is a high potential integrating the logistic processes to accelerate the throughput of goods in rail freight terminals. It has been found out by studying the processes in several rail freight yards that the linkages between the executing actors of the transport chain are not well adjusted.

The efficiency in existing transport chains for port hinterland transportation generally differs from theoretic models (see [3]). A low coordination between the participating actors of today's railway based hinterland transportation leads to a low level of adjustment of the single processes. This leads to long lasting transhipment processes in the terminals and shunting yards, untimely trains and long transportation times. To compensate delays, time buffers are planned by the railway operators which again extends the transportation time.

Those non-productive time periods, caused by low coordination, consume time but also infrastructure capacity. They arise when the costs for coordination are considered as too high due to opportunism and bounded rationality (see [3]). The problem therefore must be seen as a community problem which can not be solved by one single actor who is not willing to pay for a solution to benefit all participants among the transport chain.

3.1. Deviation of arrival times

The process flows in rail freight yards are orientated towards the achievement of terminal slots (for export flows) or network track slots (for import flows). Therewith the last element of the process chain is critical and all other processes have to be settled before. In theory, the duration of a certain element of the process chain can be estimated and thus a string of processes can be created to meet the slot in the end on time as it will be shown in section 3.3. In reality, a set of time divergences occurs that makes it difficult to assess process durations. To explain this more precise, the export stream (flows coming from inland destinations to the seaport) shall be regarded more precisely:

Freight trains arrive at destination stations with a certain variance of their planned arrival time. This deviation varies in a range of several hours to early till several hours of delay. Trains arriving too early have no negative effect on subsequent logistic processes. Nevertheless it shall be mentioned that they consume capacities in the rail yard to wait for their further use. The delay of arriving trains on the contrary should be considered in the organisation of subsequent process flows. It can be depicted as a negative exponential distribution function. For a couple of trains the following probability function as been computed:

$$p_{arr} = e^{-0.037 t_{delay}} \quad (1)$$

It describes the probability of arrival p_{arr} for a train with a delay of t_{delay}. The function may differ for respective railway yards as well as for the trains involved but a negative exponential distribution function can be assumed as a general assumption to illustrate delays.

3.2. Time buffers to absorb delays

One problem in rail freight transport is the absence of information transfer about delays to subsequent actors but also their disability to react on delays. Thus, delays propagate in subsequent processes up to the slot for the loading siding. In complex terminals the time slots in which a train is planned to be loaded / unloadad are not flexible enough to absorb the delays. Usually slots are rather inelastic and can only be cancelled but not moved or swapped. This would require powerful planning tools including the ability of rescheduling which do not yet exist sufficiently.

Railway operators in consequence use planning of additional buffers in time tables to absorb possible delays. That explains why freight trains may arrive much too early because in many cases the time buffers are not needed. As a result the early train requires a holding track in the rail freight yard to wait until the next logistic step can start. During the idle time period trains need infrastructure capacities without being involved in production processes.

3.3. Process chains in railway yards

As mentioned above, the last element of the process chain is critical. Preceding elements of the process chain must fit with it. Regarding the export stream (flows from inland destinations to the seaport) the process chain can be split into four elements:

1. **Sorting:** After the train's arriving at the railway yard a couple of processes are summarised as sorting. They contain elements such as wagon check and shunting of wagons
2. **Time buffer:** An unproductive period to compensate possible delays of arrival.
3. **Shunting:** Groups of wagons which have been formed in the sorting process are moved to a terminal's loading siding for loading and unloading.
4. **Terminal:** The last element, describes the loading and unloading procedure.

Each element of the process chain requires a certain period. In this paper a fixed duration for each element of the productive processes (sorting, shunting, and terminal) is assumed. Thus, the time buffer becomes a flexible element whose value depends on the delay of the train arrival.

Figure 3 illustrates the scheme of the process chain in rail freight yards in three cases. The three cases (A - C) demonstrate the decline of time buffers with increasing delay. Case A shows a train on time which causes a big time buffer within the rail freight yard and a long period of non-productivity. Case C, on the contrary, shows a delayed train which does not produce any time buffer. It leads to optimal infrastructure capacity utilisation but the whole process chain is critical.

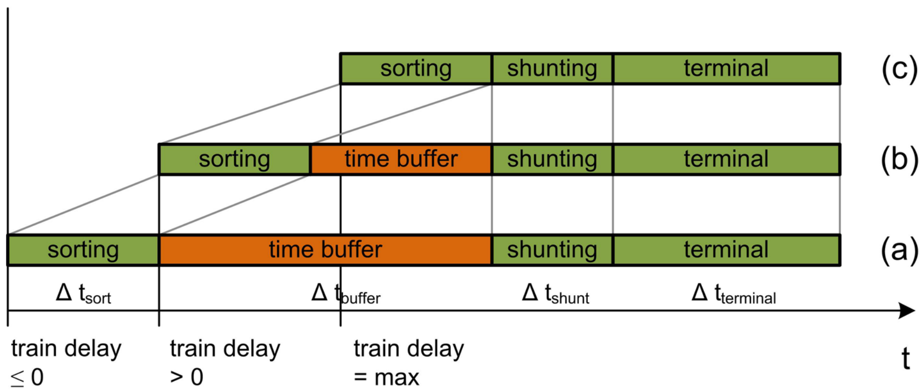

Figure 3. Illustration of three process chains in a railway yard. All processes of the production process (sorting, shunting, terminal) have a fixed duration. Time buffer is flexible as it is not part of the production process. (a) Train arrives not too late: time buffer is big – high share of unproductiveness. (b) Train arrives with delay: time buffer shrinks. (c) Train arrives with maximum delay: no time buffer left, further delay implies loss of terminal slot.

For a random sample of around 50 trains the time buffers have been examined in an empirical study. The period for loading and unloading ($\Delta\ t_{terminal}$) as well as the period for shunting ($\Delta\ t_{shunt}$) could have been observed. It became evident that these periods differ for each train but with a low standard deviation so that the determination of discrete periods was possible. The loading period has been defined as $\Delta\ t_{terminal} = 360$ min, the shunting period as $\Delta\ t_{shunt} = 30$ min. For the sorting process a period $\Delta\ t_{sort} = 240$ min has been assumed which gives sufficient time for necessary railway operational and logistic tasks such as uncoupling the locomotive, paper and wagon check sorting of wagons, or customs control. In this context it shall be mentioned that for block trains which are mostly used in combined transport a $\Delta\ t_{sort} = 60$ min is sufficient.

The moment of arrival of each train is given as well and thus the time buffer Δt_{buffer} is determined by the range between the end of the sorting process t_{sort}^{end} and the start of the shunting process t_{shunt}^{start}.

3.4. Estimation of time buffers for a sample train set

The time buffers for the examined train set have been calculated and evaluated. It became evident that the buffer process period is subject to a high variance. While some trains have a theoretically negative buffer time[1], others are stored for more than 24 hours. Though it is hardly possible to estimate a generic time buffer value, some quantitative conclusions can be made.

By the examination it was possible to calculate the productivity of the infrastructure in rail freight yards. The productivity in this case determines the time where infrastructure is occupied for production processes in relation to the time where infrastructure is occupied:

$$productivity = \frac{\sum \Delta\ production\ \ processes}{\sum \Delta\ all\ \ processes} \tag{2}$$

For the examined sample of trains the productivity amounts to 63.297%. It implies that more than one third of the time infrastructure is used for non-productive processes, respectively for buffer times. In detail, the share of each process as defined in section 3.3 is as follows:

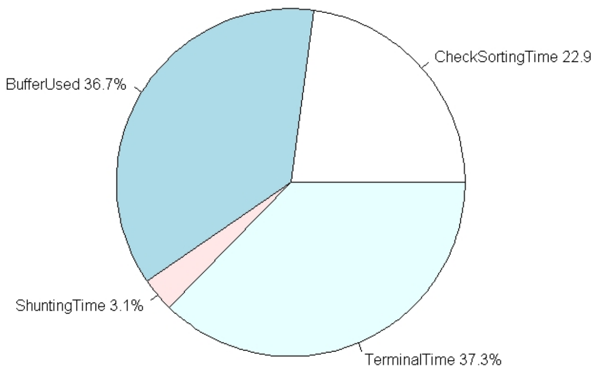

Figure 4. The share of non-productive time is more than one third.

[1] The theoretically negative buffer times arise from trains which require less than 240 minutes for the sorting process but have only a small time buffer planned. Thus, a negative buffer time can be calculated.

3.5. Evaluation of time buffers

The non-productive processes in a rail freight yard behind a seaport have been identified to illustrate how rail freight services are integrated into logistic supply chains. In general a supply chain is understood as a linkage between several actors to provide a common logistic product in co-operation with the aim to minimise the throughput of the goods. The success of transport chains becomes evident at system borders where actors are co-operating. At these interfaces it is necessary to exchange certain information for a fast and smooth throughput of goods.

The research at the interface seaport-rail shows that the exchange of goods and information between actors is not thoroughly performed. Because of insecurities and deviations in process flows time buffers are used in rail freight operations to ensure the achievement of the next production step. In many cases these time buffers are not needed and elongate the supply chain. In consequence, the transports on rail require more time than necessary. The issue affects also the competitiveness of the rail freight system as a whole compared to road haulage.

In high loaded freight yards the use of infrastructure capacities as storage facilities for unused trains can become a problem because the space for necessary railway operations decreases. For the purposes of the infrastructure manager the high utilisation of its facilities is of course favourable since for every stored train track access charges can be imposed. From the economic point of view a high utilisation leads to congestion and thus to further problems as in every network.

Time buffers in railway yards can be understood as storage facilities for freight trains as a counterpart of the general storage facilities for goods at the other side of the interface seaport-rail. Figure 5 illustrated the concept. However, due to extremely high infrastructure costs the time buffers should be reduced to a minimum value. Storage processes should be concentrated at one place within a seaport. Railway infrastructure and vehicles should not be used as storage facilities.

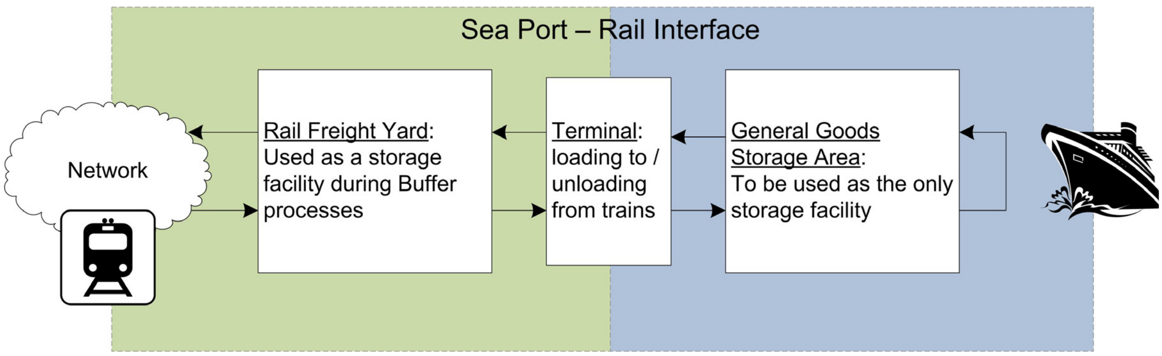

Figure 5. Location of storage facilities in seaports – For economic reasons a storage of goods and wagons in the rail freight yard shall be avoided

4. SOLUTION APPROACHES TOWARDS THE REDUCTION OF TIME BUFFERS

With the reduction of time buffers and thus a better integration of railway processes the transport chain shall be better adjusted and the ship-to-rail transhipment flow becomes smoother. Two possible ways of integration are shown in this section. First, the integration of processes shall be performed by an improved communication between the actors involved in the supply chain. Second, a floating interface using inland hubs is presented.

4.1. Elementary integration using an information flow model

A first approach towards a better integration of railway freight services in supply chains is the reduction of plan variances and insecurities in process flows. With a higher reliability the time buffers can be reduced and rail freight transport can be accelerated. To achieve a better integration, a comprehensive information flow between the actors involved in the transport chain is necessary. Which information is necessary for which actor, will be displayed in an information flow model.

The information flow differs for the import and the export direction. As in this paper mainly the export flow has been examined, the following information flow model also describes the export flow. Figure 6 illustrates the information flow model for export routes. As it has been depicted in chapter 3, the model starts from the seaport terminal's time slot data at the top of the figure which are assumed to be less flexible. At the bottom of the figure the arrival times of incoming trains are shown, as well-known, with a possible deviation. The processes of sorting and shunting are located between them.

By giving continuous information about the process status to the following actors the progress of the transhipment processes is kept constant. Thus, the seaport terminal is able to estimate whether a certain train is able to catch its time slot early. The marshalling yard, the shunting operator and the railway operator are in possession of necessary data to plan their own processes more effective and to lower plan variances. The information flow is organised in two directions: A top down flow delivers the planned data. A bottom up flow delivers the estimated divergences.

An improved flow of information will of course not eliminate time buffers. However, by using an integrated information flow system and methods of real time scheduling for processes in rail freight yards they can be reduced to a minimum value. A reasonable organisation might be for example a scheduling of the rail freight yard capacities with a forecast of 24 or 48 hours combined with the possibility of dynamic rescheduling to absorb train delays from the network.

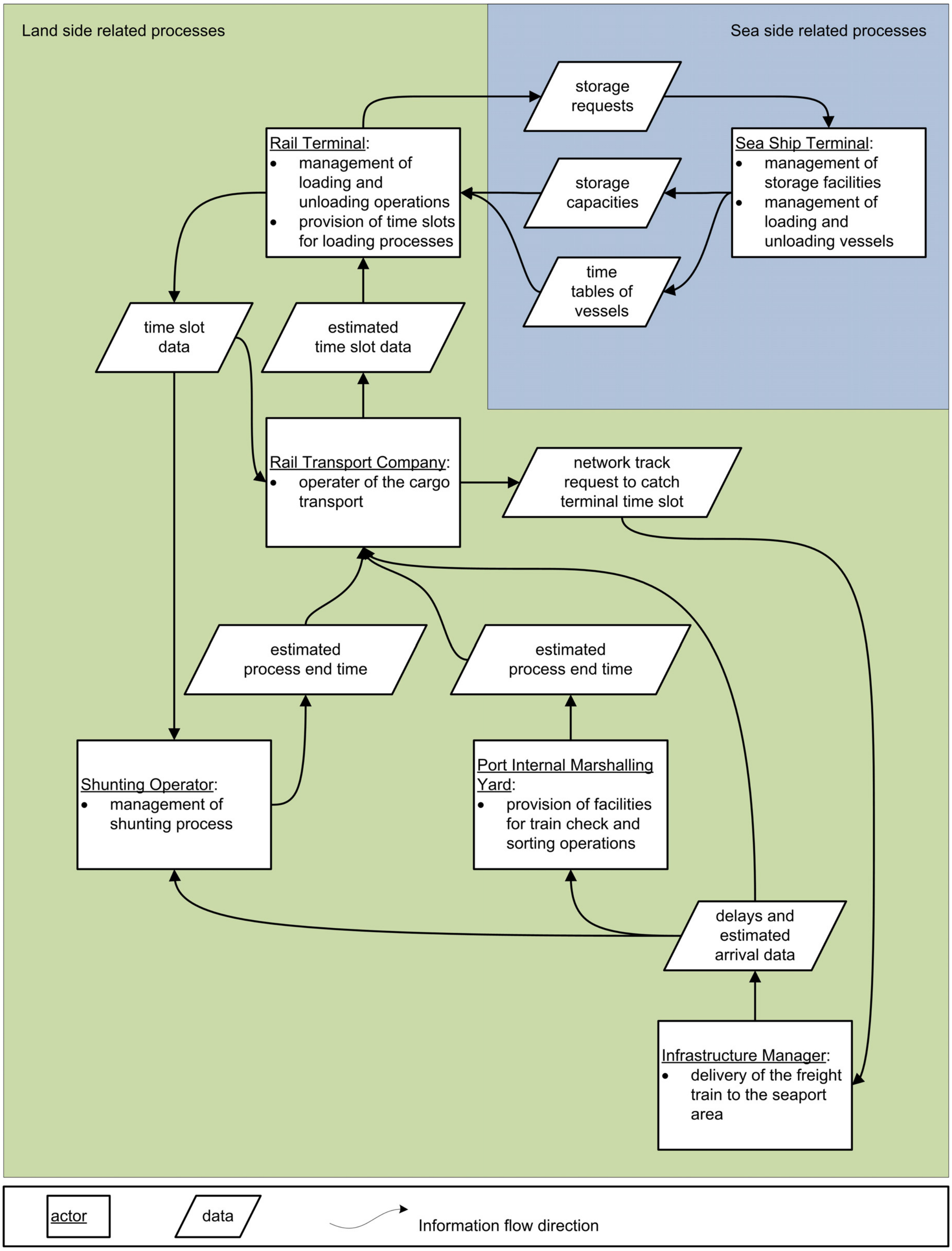

Figure 6. Information Flow Model for export routes to seaports. The land side related processes are illustrated in-depth. The sea side related processes are compressed since they are not the object of the article.

4.2. Floating interface with two transhipment processes

A second idea to integrate rail freight services in transport chains is the establishment of floating transhipment interfaces using inland hubs. Here, the time-consuming processes shunting and sorting shall be reduced. This leads to more standardised rail transports. Furthermore, the advantages of rails – the haulage of heavy good on long routes – can be cultivated.

Basic idea of inland hubs is the reduction of direct connections between a seaport and its hinterland. All goods from seaports, except the loco quota, are transferred by railway links to terminals in the hinterland, see Figure 7. Ideally, only shuttle block trains, which will not be divided or sorted, are used for those services. Shunting processes are reduced to a minimum.

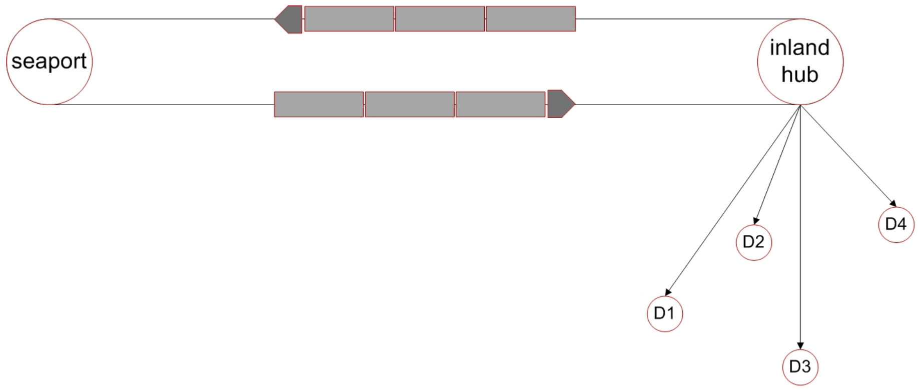

Figure 7. Shuttle block train concept for port – inland traffic

Not until a shuttle trains reaches the inland hub the transhipment starts actually. Here, transhipments to other trains or to trucks are performed. The Solution provides possibilities to introduce innovative transhipment technologies which already exist but have not found their acceptance on the market, e.g. automatic systems for horizontal transhipment rail to rail.

By using inland hubs, some coordination tasks can be dropped because the railway operational processes are extremely simplified. For the transfer of a certain good from a seaport to the inland terminal it is not important which freight car is used. The next empty wagon will serve in every case. While the good is beeing hauled to the inland hub further transport procedures can be planned.

To introduce such a system successfully, some conditions are to be followed, e.g.:

- high speed freight train shuttle of maximum length
- shuttle connection frequency (e.g. twice/h)
- punctuality (e.g. above 85%)
- must have an assured network route
- usage of fast and compatible turnover equipment
- economic and utility calculation:
    - The additional turnover in inland terminals must not be more expensive than a direct transport to/from the seaport (pareto criterion 1).

- o The additional turnover in inland terminals must not need more time than a direct transport to/from the seaport (pareto criterion 2).
- Operator: Is the parallel activity of several operators on one shuttle relation possible in a competitive situation?

5. CONCLUSIONS AND OUTLOOK

The railway industry is known to be a rather conservative branch where it is difficult to establish technological development. The cause can be seen in the mostly big railway operating companies with a certain market power on the one hand and with a lack of action according to changes on the other hand. In addition, some actors among the transport chain in rail freight operation are not willing to pass information to other actors. This is understandable as there are competitors around who shall not obtain sensible operation data but this behaviour leads to a slowing down of the transport chain as a whole and to the today's situation in rail freight operations:

- low reliability, no smooth flow of processes
- insecurities according to train arrivals and time table reliability
- no linkage between loading slot times and network track access
- no efficient scheduling of shunting operations
- high amounts of time buffers consume infrastructure capacities and extend transport times

By passing certain information to subsequent actors of the transport chain the process flow will become smoother and more reliable. Each actor then would be able to plan his own work processes more precise.

The basic design of a general information flow model has been represented. Now, the concrete implementation of such a model has to be developed. In further research it is to assess how big buffer time savings can be with the usage of information flow models. To solve the community problem, the outcome of buffer time savings must be higher than the costs of an information flow system.

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