Report on new ways for last-mile operation methods

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Involved partners

Following project partners have been involved in the elaboration of this document:

Partner N°	Organisation short name	Involved experts
1	HaCon	Eckhard Riebe, Niklas Galonske, Felix Hildebrandt
2	ETH Zürich IVT	Albert Mancera, Tobias Fumasoli, Dirk Bruckmann
3	SBB Cargo	Katharina Litwin, Thomas Fuchs, Patrik Dober

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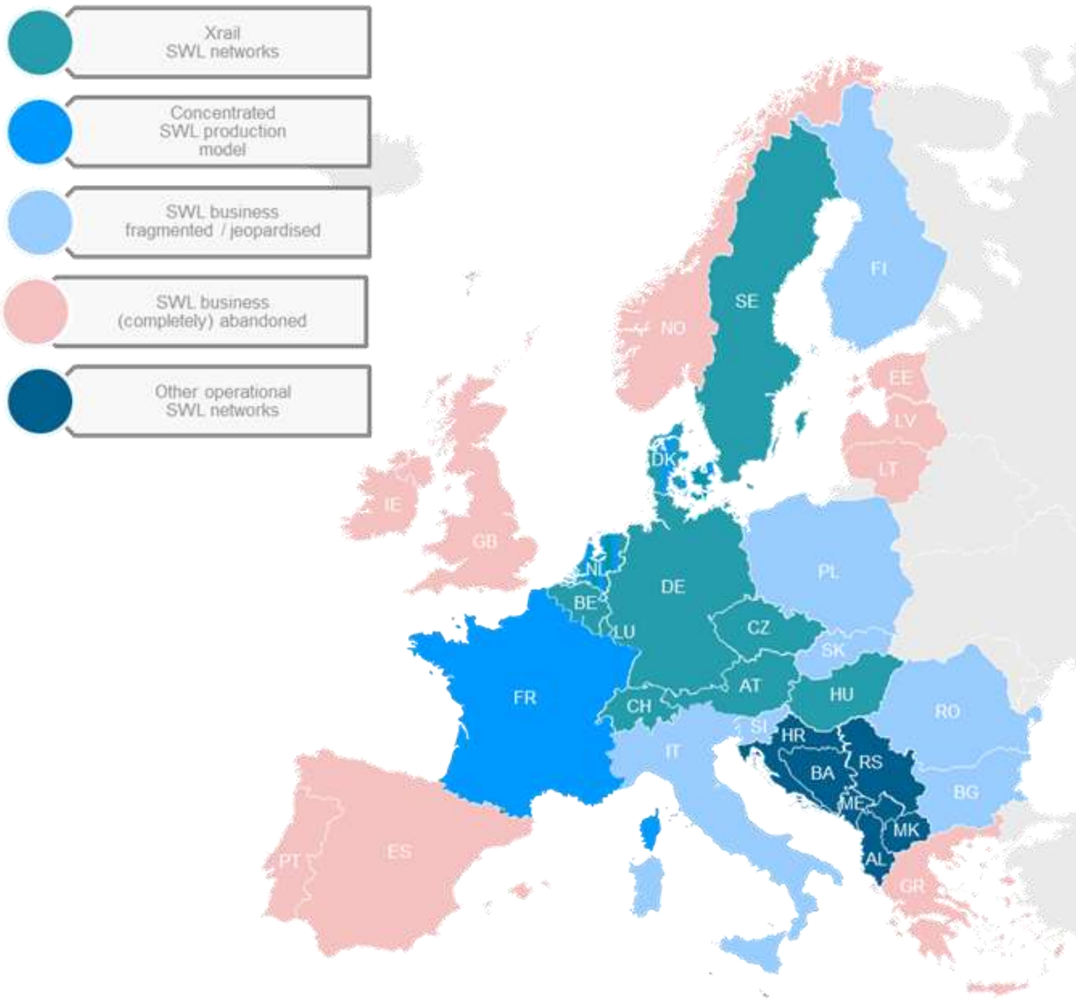
a.m.	Ante meridiem
BC	Business Case
CHF	Swiss currency
ft	Foot
et al.	Et alii
Hbb	Specific wagon type
i.e.	For example
ISO	International Standards Organisation
km	Kilometre
KPI	Key Performance Indicator
Ks	Two-axle standard flat wagon type with a wooden floor
Lgns/Lgnss	Two-axle container wagon type
m	Metre
MATSim	Multi-Agent Transport Simulation Toolkit
mm	Millimetre
p.m.	Post meridiem
RB	Rangierbahnhof (shunting yard)
Res/Rs	Four-axle standard flat wagon type with a wooden floor
SBB	Swiss railway company (Schweizerische Bundesbahnen)
Sgns/Sgnss	Four-axle container wagon type
SWL	Single wagonload
t	Tonne
TEU	Twenty foot-equivalent unit
RCP	regional production points (Regionale Cargo Produktion)
UIC	International Union of Railways
WP	Work Package

1 Introduction

Freight transport in Europe has been increasing due to changing production strategies and the introduction of international free trade agreements. However, the demand for rail freight transport has been decreasing since the 1970s due to changes in the types of transported goods (i.e. the shift away from bulk towards manufactured goods) and new logistics strategies such as decreases in inventory as well as a focus on flexibility, reliability and smaller but more frequent deliveries. These factors have all contributed to shift freight transport from rail to road.

At the same time there has also been a shift from single wagonload (SWL) traffic to block-trains and combined transport. European countries have adopted differing approaches to address this problem. The overall operations shall be improved through bundling of SWL traffic. Figure 1 illustrates the current situation of European SWL.

Figure 1: Current situation of European SWL network



Source: HaCon

As shown above, Germany, Sweden, Belgium, Luxembourg, Switzerland, Austria, Czech Republic and Hungary have joined the Xrail alliance. The Xrail alliance is a new cooperative business model to operate the international SWL in Europe. Each of the partners is responsible for the national SWL transport in their respective country – international SWL transport however was shifted from a competitive business model to a cooperative business model to increase the efficiency of SWL transport. The partner countries still consider SWL traffic as an important component of the freight transport system and are working to optimise their production schemes within the Xrail alliance. France has taken the approach of optimising SWL production schemes by focusing on a concentrated network covering the major economic centres. In Eastern Europe and Italy, the SWL network is only being operated in a fragmented manner and its long-term viability is threatened. In Spain, Portugal, the UK, Greece and Norway, there is no SWL network at all.

A key goal of the European transport policy is shifting transport volumes to environmentally friendly modes such as rail. While there are always ideas to substitute containerised systems for SWL, there are still market segments such as steel, automotive and forestry that are highly dependent on SWL. Furthermore, a working SWL system remains necessary to fulfil the logistics requirements of many other shippers, even if they only ship a small share of their goods via SWL. In short, the SWL business remains important for European transport, but significant improvements are needed to enhance the competitiveness of SWL in respect of the current market trends. This paper describes the ViWaS approach for improving SWL networks.

This deliverable "Report on new ways for last-mile operation methods" (WP 6) examines possibilities to optimise the last-mile operations which are considered as crucial to reduce the overall SWL production costs. The research work will be done with a special focus on the business cases as identified in WP 5 and reported to the EU Commission in D5.1 "Report on market-driven business models and production systems".

This document aims to examine possibilities for containerised SWL traffic, focusing on last-mile operations. Therefore, the first step is to identify operational obstacles for the integration of combined traffic in the SWL network. Several Swiss sidings have been visited by members of IVT, SBB Cargo and Wascosa in order to detect all possible operational obstacles. Measurements have been carried out as well as container loading/unloading tests and interviews with siding operators to collect their professional expertise.

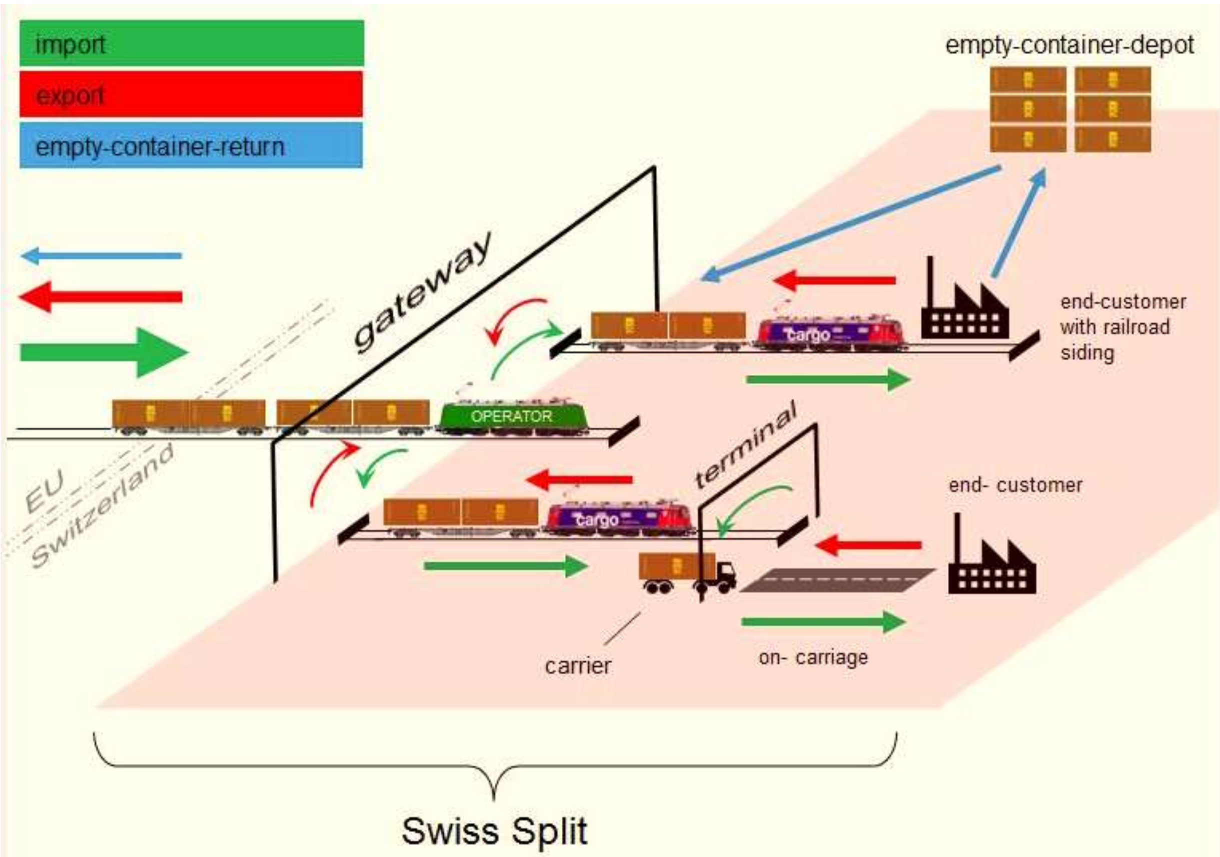
Within WP6 it is intended to elaborate an advanced SWL/intermodal production concept on basis of Swiss Split procedures. Therefore, after processing the previously mentioned information, an innovative wagon platform has been designed, built and is currently being tested to improve intermodal procedures in Swiss Split (cp. WP7 "Technologies" and WP10 "Demonstration"). Further activities within WP6 are the development of solutions for a cost-optimised cargo collection/delivery (cp. D6.1, part 2), the evaluation of hybrid locomotive traction schemes (cp. D6.1, part 3) and finally a simulation of SWL production schemes with the software tool MATSim (described within this document: D6.1, part 1). This simulation will indicate the current situation of the network according to certain KPIs specifically selected for that purpose and also will allow for testing of different solutions to improve the current traction schemes of Swiss Split and SWL networks in general.

2 The Swiss Split

2.1 Introduction to the Swiss Split concept

The Swiss Split is a product of SBB Cargo for the distribution of maritime containers to the final destination sidings by rail. Figure 2 illustrates the entire transport chain from the oversea port to the final recipient in Switzerland including the Swiss Split. Shuttle trains or barges transport the containers from the seaports to the existing transhipment terminals in Switzerland. The containers are transhipped in the Swiss hinterland terminals from the long-haul trains or the barges to standard flat-wagons or container wagons of the national single wagonload network. The wagons are then transported within the existing SWL production network of SBB Cargo into the sidings of the final recipients. Afterwards, they are placed at the existing SWL loading ramps where the containers are unloaded by forklifts or industrial trucks. Figure 3 shows an example siding. At present, Swiss Split is a worldwide unique concept. There are a few special services in the German chemical industry existing, or in big distribution services around Europe, but there is no another business model as Swiss Split that connects maritime containers with direct load and unload on the wagon in private sidings.

Figure 2: Schematic diagram of Swiss Split services



Source: SBB Cargo

Figure 3: Standard flat wagon with Swiss Split-Container at the recipients' ramp

Source: IVT

In 2013, about 41,783 wagons loaded with 53,598 containers were transported within the Swiss Split. On a basis of an overall amount of 3,000 SWL wagons per working day in the SWL network of SBB Cargo, about 6 percent of all SWL transports are related to Swiss Split. Thus, Swiss Split assures an important part of the base utilization of the Swiss SWL network.

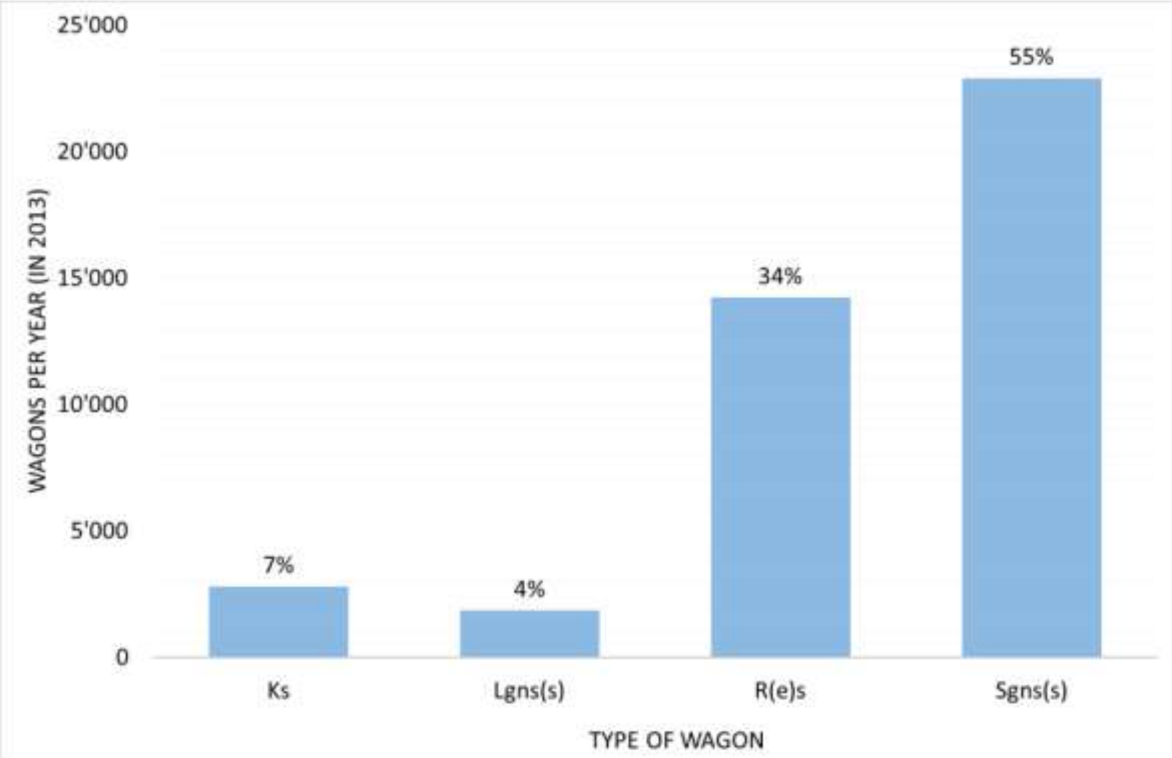
2.2 Currently operated wagon types in Swiss Split

Nowadays, two general types of vehicles are used in the Swiss Split: standard flat wagons with wooden floor and conventional container wagons, both types in versions with two and four axles. The big difference between both types of vehicles is the "missing" floor of the conventional container wagon. Industrial trucks (forklifts and hand lift trucks) are therefore unable to operate on the container wagons and additional equipment like moveable ramps is required to unload the maritime container (with doors only at the rear). Thus, the loading ramp covers the missing floor of the container wagons.

These wagon-types are yet in use for the Swiss Split:

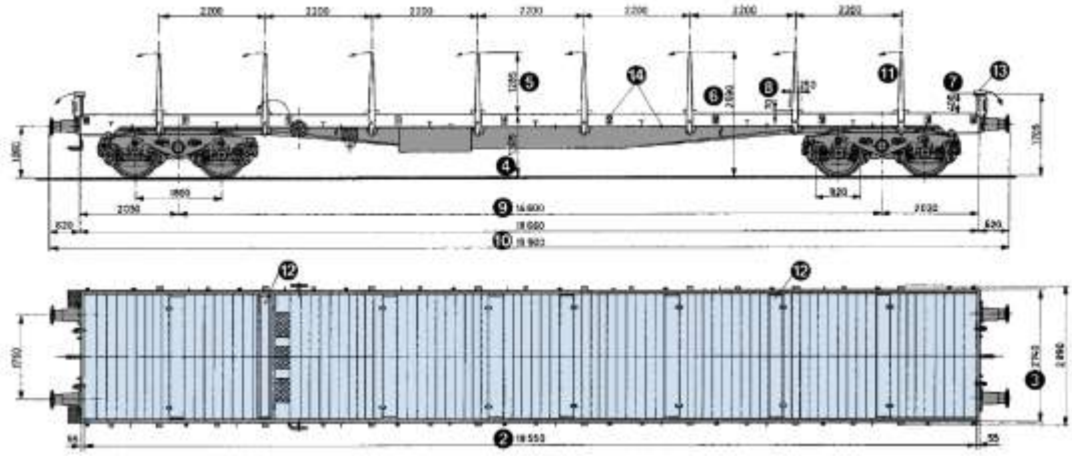
- Two-axle standard flat wagons with a wooden floor, type Ks;
- Four-axle standard flat wagons with a wooden floor, types Res and Rs;
- Two-axle container wagons, type Lgns and Lgnss;
- Four-axle container wagons, types Sgns and Sgnss.

Figure 4: Distribution of wagon types in Swiss Split in 2013



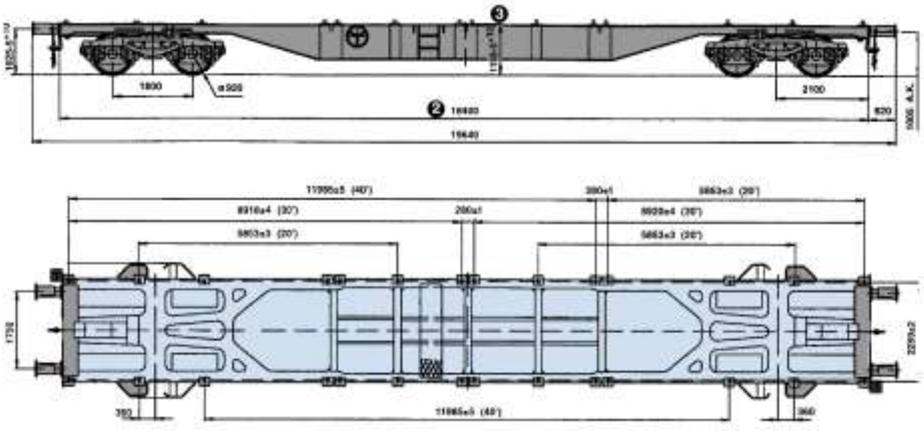
Source: Data from SBB Cargo, graph from IVT

Figure 5: Rs wagon



Source: SBB Cargo

Figure 6: Sgns/Sgnss wagon



Source: SBB Cargo

Table 1: Comparison Rs and Sgns/Sgnss

	Rs	Sgns/Sgnss
Tare weight	24 t	20 t (Wascosa light: 17.4 t)
Max. loading weight	56 t	70 t (Wascosa light: 72.6 t)
Length over Buffer	19,900 mm	19,640/20,050 mm
Loading height above rail level	1,260–1,305 mm	1,155 mm
Loading length	18,500 mm	18,400/18,720 mm
Loading width	2,740–2,766 mm	2,438/2,550 mm (external dimensions ISO/WB)
smallest navigable curve radius (single wagon)	35 m	75 m

Source: SBB Cargo

Table 2: Wagon loading heights in SWL and combined transport

Covered wagons		**Flat wagons**	
Type	**Deck wagon heights above rail level**	**Type**	**Deck wagon heights above rail level**
Habbillns	1,200 mm	Ks	1,235 / 1,241 mm
Hbi(l)s	1,200 mm	Rs	1,305 / 1260 mm
Hbbillns	1,200 mm	Res	1,260 / 1235 mm
Hbbills-uy	1,240 mm	Sgns	1,155 mm
		Lgns	1,155 mm

Source: SBB Cargo

59 percent of all wagons transported in Swiss Split are standard container wagons, but about 41 percent of the transported wagons are still quite old wooden floor flat wagons.

The decision on the type of vehicle used for a specific shipment depends on the technical equipment available in the destination sidings. Larger sidings are often equipped with specific transhipment equipment to load/unload the containers. In smaller sidings, most commonly available transhipment equipment are forklifts or hand lift trucks. They can move on the wagon itself via crossing gangways between the loading ramp and the wagons. To operate the forklifts or hand lift trucks, the wagons need a continuous floor. Hence, conventional container wagons are not usable on smaller sidings.

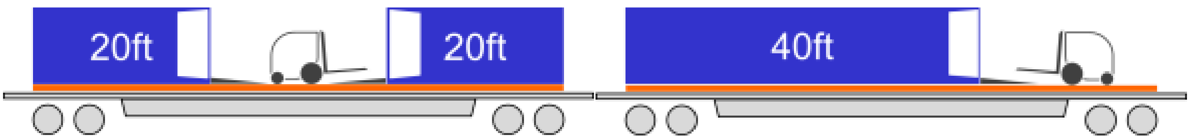
Most of the flat wagons with wooden floor have reached the end of their economic life cycle. As the securing of the containers on these wagons is quite complicated (the containers have to be fixed by nailed wooden blocks, thus cost and time consuming), SBB Cargo is developing an "economic" wagon type for an optimised handling of Swiss Split containers in rail sidings within the ViWaS project. The main idea of SBB Cargo is to replace the flat wagons by Sgns/Sgnss wagons equipped with a platform that covers the wagon surface allowing the siding operations required to load and unload the containers.

2.3 Functional requirements of the platform

2.3.1 Dimensions and Structure

The platform should be compatible with the standard 60-ft container wagons (Sgns/Sgnss). It is designed to be placed on top of the wagon, as a new deck. It should cover the entire wagon surface, meaning that the containers (1x40-ft or 2x20-ft) will be placed on top of the platform. A Sgns/Sgnss wagon equipped with a platform should be handled in the same way as Rs wagons.

Figure 7: Schematic diagram for 20-ft and 40-ft containers



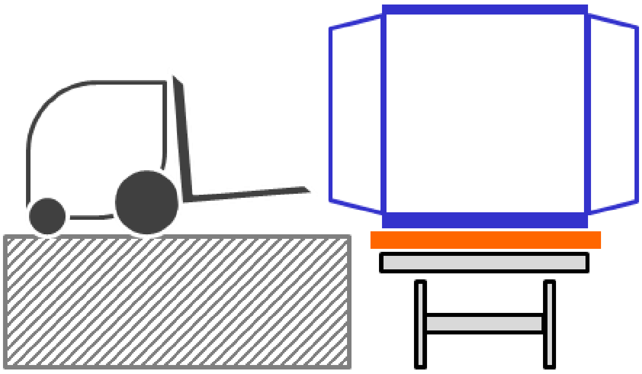
Source: IVT

Therefore, the platform must fulfil the following conditions:

- Length of a 20-ft ISO container.
- Minimum width of a Rs wagon (2,740–2,766 mm).
- Maximum width according to UIC-Codex 592 (2,930 mm).
- Placed at standard positions of the wagon spigots.
- Each platform is equipped with at least 8 spigots to hold 20, 40, and 45 feet containers. The spigots are compatible with the spigots already in use on container wagons.

- Placed in groups of 3, to cover the full length of the wagon (60-ft).
- Side socket for the guardrails need to be integrated. The guardrails are a recommendation, but are not part of the delivered platform.
- The platform must be mountable on different wagon designs of the type Sgnss (longitudinal beams inside or outside).
- The platform must be able to be placed in any position of the 3 possible.

Figure 8: Schematic diagram of the front view



Source: IVT

2.3.2 Handling in container terminals

The containers, originally from the (international) combined transport trains, are loaded on SWL trains at the container terminals. The platform is also placed on the wagon at the container terminals. Similarly, the platforms are unloaded from the wagons, collected and sent back to the starting point at the terminals. Therefore, the following functions must be ensured:

- Lift the platform with the usual portal crane.
- Drive-on surface for hand pallet trucks, low lift trucks and forklifts.
- Stackable, i.e. stack transportable and interchangeable.

2.3.3 Handling in the sidings

At the siding platform the clients load or unload the containers transported on the wagons. This is done with a hand pallet truck, low lift truck or forklift. Some clients use also rolling bins. Therefore, both the axle and the diameter of the wheels of the vehicles are taken into account concerning the manoeuvrability on the platform.

The following functions must be ensured:

- Opening and closing of the container doors must be allowed when the platform is placed on the wagon.
- Drive-on allowance of motorized handling vehicles of different sizes.
- Drive-on allowance of rolling cages and pallet jacks.

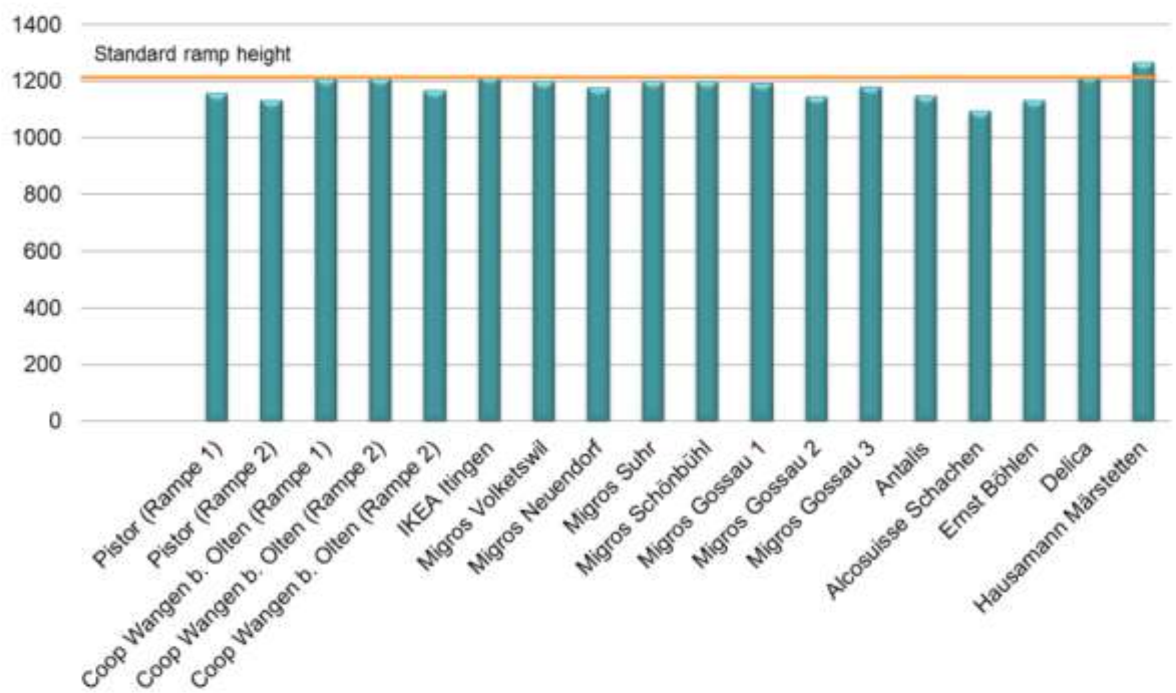
- No additional equipment needed from the customer for the transition from the platform into the container.

Note: Conventional loading ramps shall be provided to the customer for the transition from the loading platform onto the platform.

The standards for the design of transhipment facilities (Verein Deutscher Ingenieure, 1992) suggest a ramp height of 1,200 mm over track and a vertical distance between track axis and ramp edge of 1,700 mm. However, it could not be guaranteed that every siding owner has considered this standard when building or renewing its ramp.

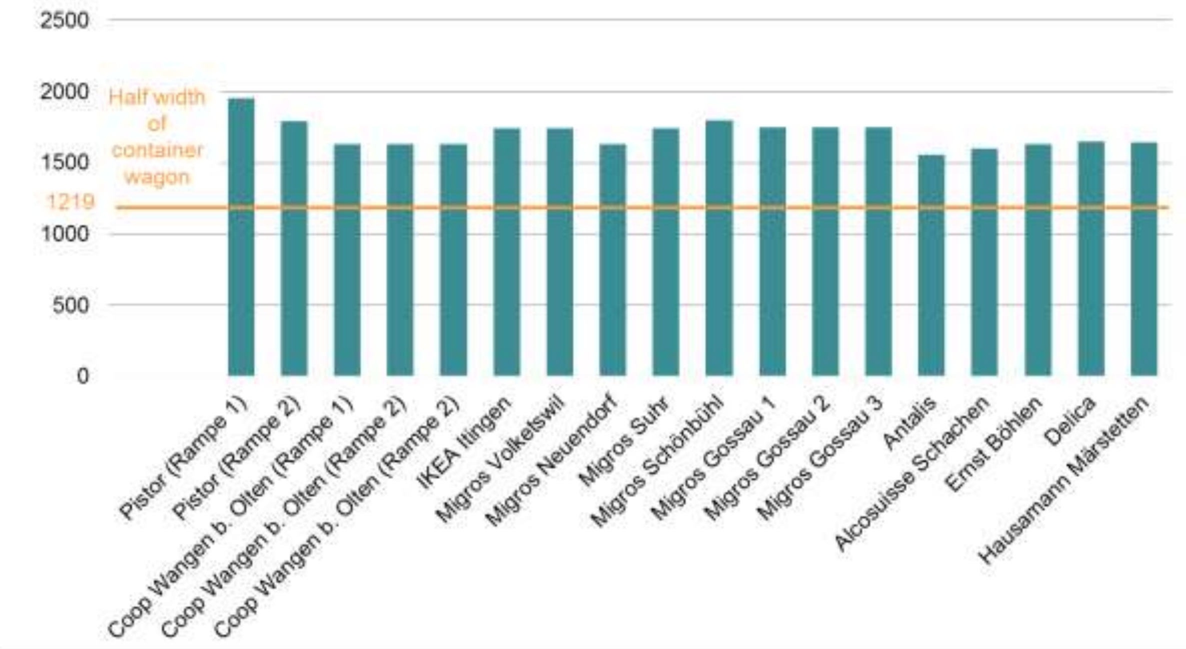
Thus the height and the vertical distance to the axis of the rail track were measured for several characteristic ramps. Most of the ramps in Switzerland are in a range of 1,200 mm (Figure 9). Only very few ramps are slightly lower or higher.

Figure 9: Height and vertical distance of the ramps (mm over track height)



Source: Wascosa

Figure 10: Vertical distances between track axis and ramp edge (mm)



Source: Wascosa

The vertical distance between track axis and ramp varies between 1,500 mm and 1,950 mm (Figure 10). Thus, the platform can be used in each of the sidings similar to the conventional flat wagons.

2.3.4 Safety

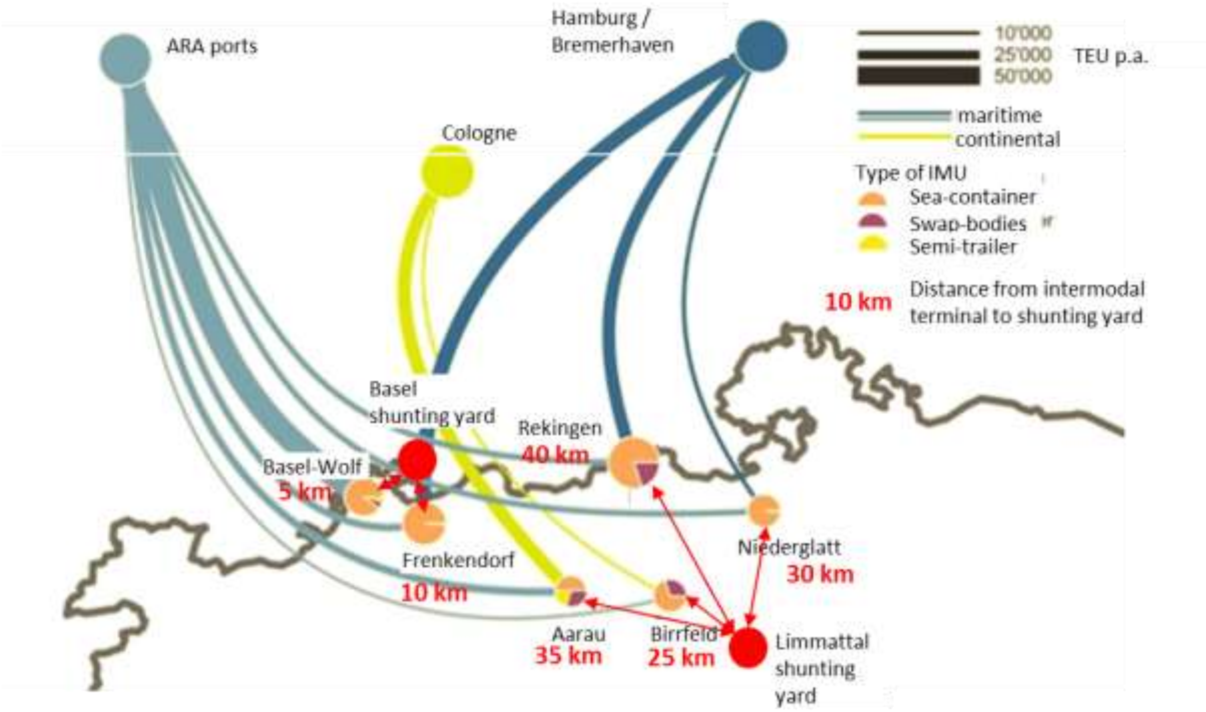
For safety and manoeuvre reasons, the platform must have a non-slippery surface. It should be considered that even though the platform operations are mostly covered, during the transport the platform will be exposed to weather conditions such as rain, snow or ice. The security measures also include appropriate floor markings.

If possible, devices for safety at work must be provided such as a drive-over protection for forklifts or railings.

2.4 New terminal structure for combined transport in Switzerland

The todays structure of terminals for combined rail-road transport in Switzerland is rather disperse. The existing terminals are of small and medium size with a capacity in the range of 30,000 to 50,000 TEU per year, which means 150 to 300 TEU per day (Ickert et al., 2012). The transport flows are rather dispersed (Figure 11).

Figure 11: Terminal structure for combined transport rail-road and related transport flows in Switzerland in 2010

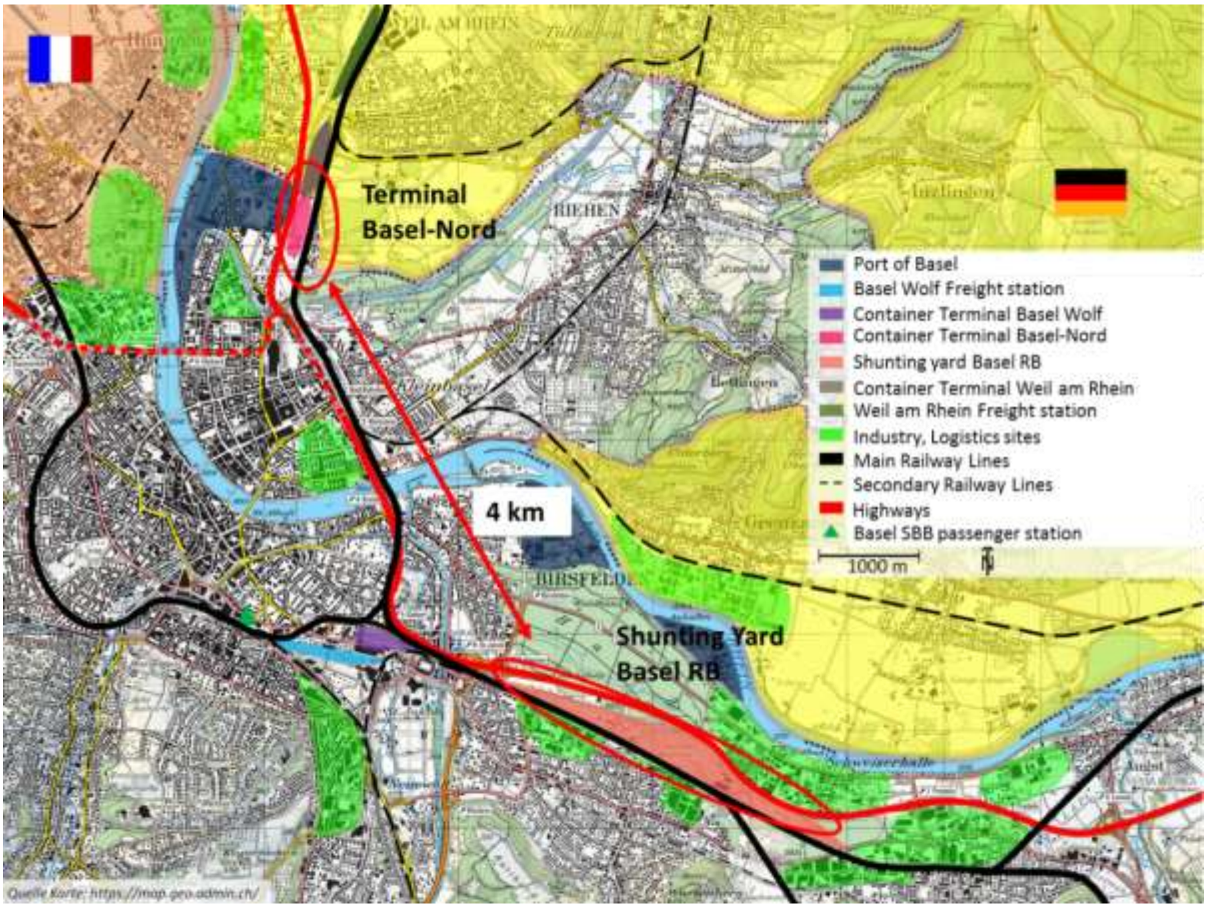


Source: Ickert et al., 2012

This terminal structure causes a rather inefficient transfer of the containers from the terminals of combined transport to the shunting yard. Each terminal has only a low volume of containers per day for Swiss Split, so that the trains from the terminals to the shunting yard are quite short. In addition, the average distance from the terminals to the next shunting yard amounts up to 40 km. Hence, the transfer of the containers in the SWL network is quite expensive and the terminals are served only once a day. This causes longer transport times for the containers to the clients. Thus, due to an inefficient use of the container wagons, the costs for the rail production in Swiss Split increase.

The goal is now to improve the terminal structure in Switzerland by introducing one main gateway terminal, where all containers for the Swiss Split can be collected. Therefore, a new trimodal (rail–road–inland waterway) terminal in Basel with a capacity up to 1,000 TEU per day is planned. This terminal shall be served directly from the seaports and most of the Swiss Split transhipments shall be concentrated at this point. Consequently, a more efficient transfer of the containers can be achieved. According to the higher demand it is possible to operate on a higher frequency of transfer-trains per day between the terminal and the next shunting yard. Furthermore, the distance between terminal and shunting-yard can be reduced to approximately 4 km.

Figure 12: Location of the new Gateway Terminal Basel-Nord



Source: IVT

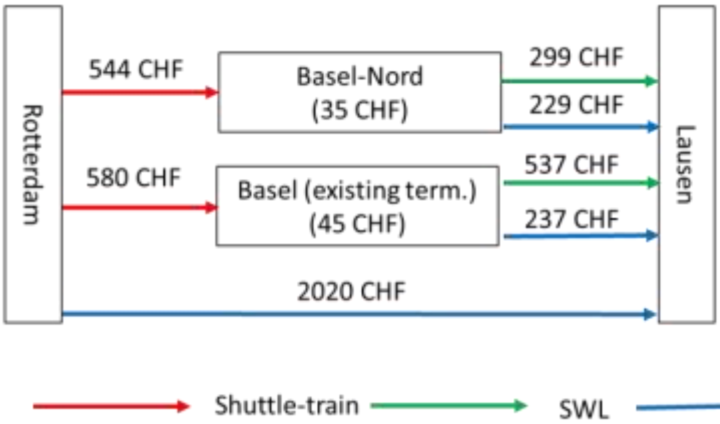
2.5 Overall feasibility of the improved Swiss Split

The IVT analysed the total transport costs for a maritime container from the port of Rotterdam to Switzerland to proof the overall feasibility of the new Swiss Split compared to the existing Swiss Split and the distribution by truck. Since the analysis considers the entire transport chain from the seaport to a recipient in Switzerland, IVT calculated with support of hwh Consulting the overall costs for a round trip transport of a standard maritime container (1.5 TEU, 16 tonnes) from Rotterdam to two exemplary destinations: Lausen (approximately 30 km from Basel) and Orbe (approximately 200 km from Basel).

The analysis was based on a transport cost model developed by hwh Consulting (Wittenbrink, 2011). It considered improvements to the efficiency of the rail and truck transport created by a better integration of the new terminal in the rail and road networks as well as reductions of the transhipment costs according to the improved terminal structure. Figure 13 and Figure 14 illustrate the improved connections.

An interpolation between the results of Lausen and Orbe shows that the break-even distance between distribution by Swiss Split and Truck distribution of maritime container decreases from 140 km to 70 km (Figure 15). Even in the short-range distribution for a distance of about 30 km from the terminal to Lausen Swiss Split becomes quite competitive to truck distribution.

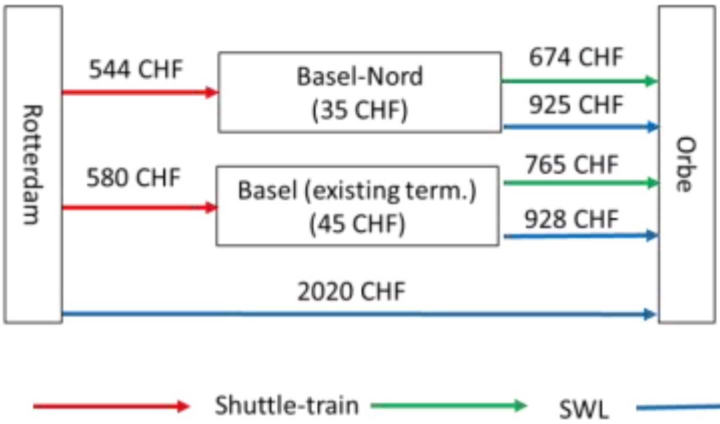
Figure 13: Transport costs from Rotterdam to Lausen



Transport route	Overall Costs
Optimized Swiss Split	878 CHF
Trucking via BS-Nord	808 CHF
Swiss Split today	1'162 CHF
Trucking via existing terminals	862 CHF
Direct Trucking	2'020 CHF

Source: IVT

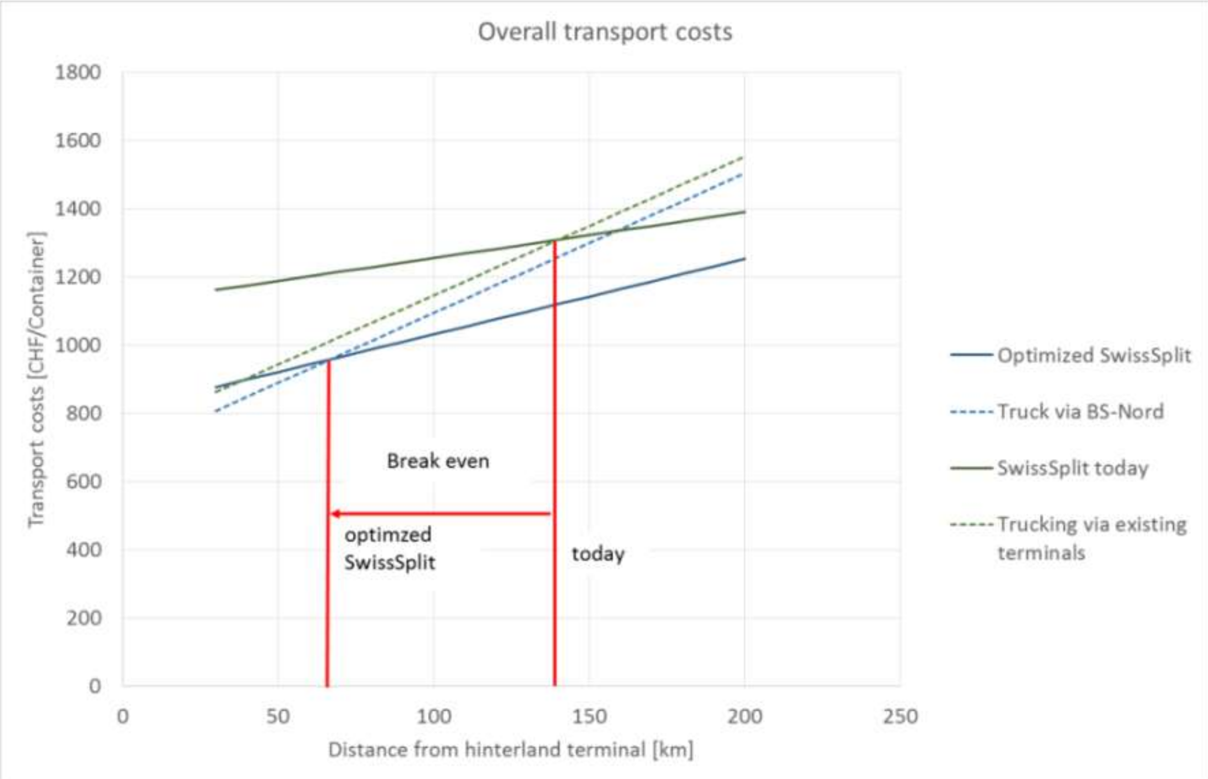
Figure 14: Transport costs from Rotterdam to Orbe



Transport route	Overall Costs
Optimized Swiss Split	1'253 CHF
Trucking via BS-Nord	1'504 CHF
Swiss Split today	1'390 CHF
Trucking via existing terminals	1'553 CHF
Direct Trucking	2'020 CHF

Source: IVT

Figure 15: Break Even distance between Swiss Split and Truck distribution



Source: IVT

3 Production scheme of the Swiss SWL network

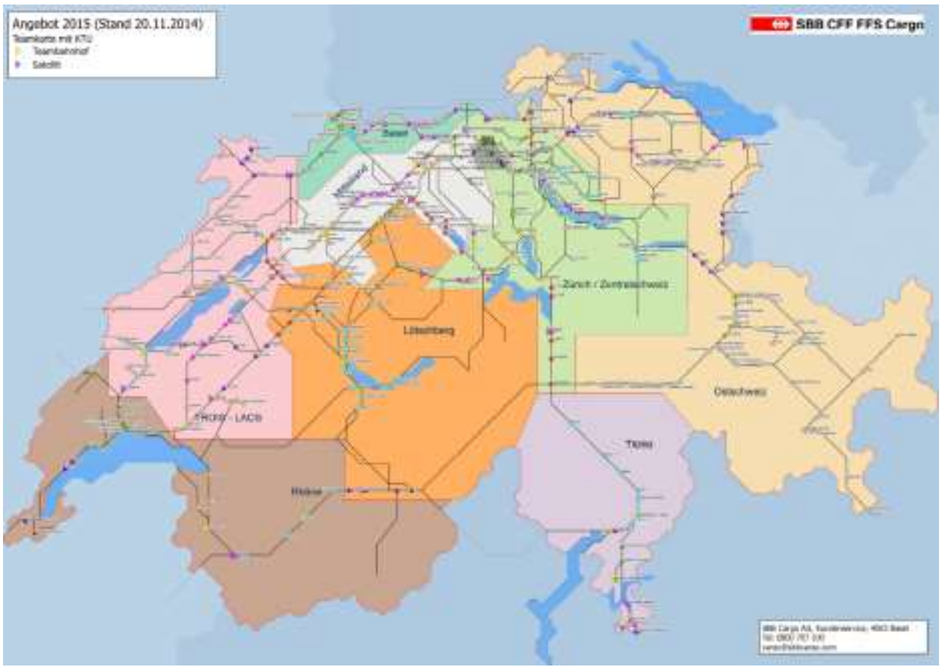
3.1 Introduction

The current production scheme of SBB Cargo for the SWL network in Switzerland is presented in this chapter together with the suggestions for improvement of the aforesaid production scheme. The purpose of this chapter is to enlighten about possible strategies to improve the SWL network in Switzerland. For that matter, IVT developed software to model the SWL network. This software allows for modeling the performance of the network and extracting certain KPIs for a subsequent analysis to evaluate the performance. Therefore, a set of variations of the current production scheme have been modeled and compared with the current one. The results show that there is room for improvement if some changes are added into the current production scheme of SBB Cargo for its SWL network.

3.2 Description of SWL network

Compared to other European Countries, the SWL in Switzerland is in a good state, meaning that over 90% of wagons reach their destination on time or with a delay of 30 minutes maximum. About 50 percent of all domestic, import and export rail transports are handled by SWL. However, even in Switzerland, the SWL faces the pending challenges. On one hand, a continuous optimisation of the production network and a reduction of the number of shunting yards take place. On the other hand, SWL in Switzerland has to deal with rapidly growing passenger traffic, which is prioritized in the network access. Thus, the number of available train paths for SWL is reduced. Especially in the peak hour of passenger transport (6 a.m. to 9 a.m. and 4 p.m. to 7 p.m.) there is a lack of train paths for SWL.

Figure 16: Current SWL network of SBB Cargo



Source: SBB Cargo

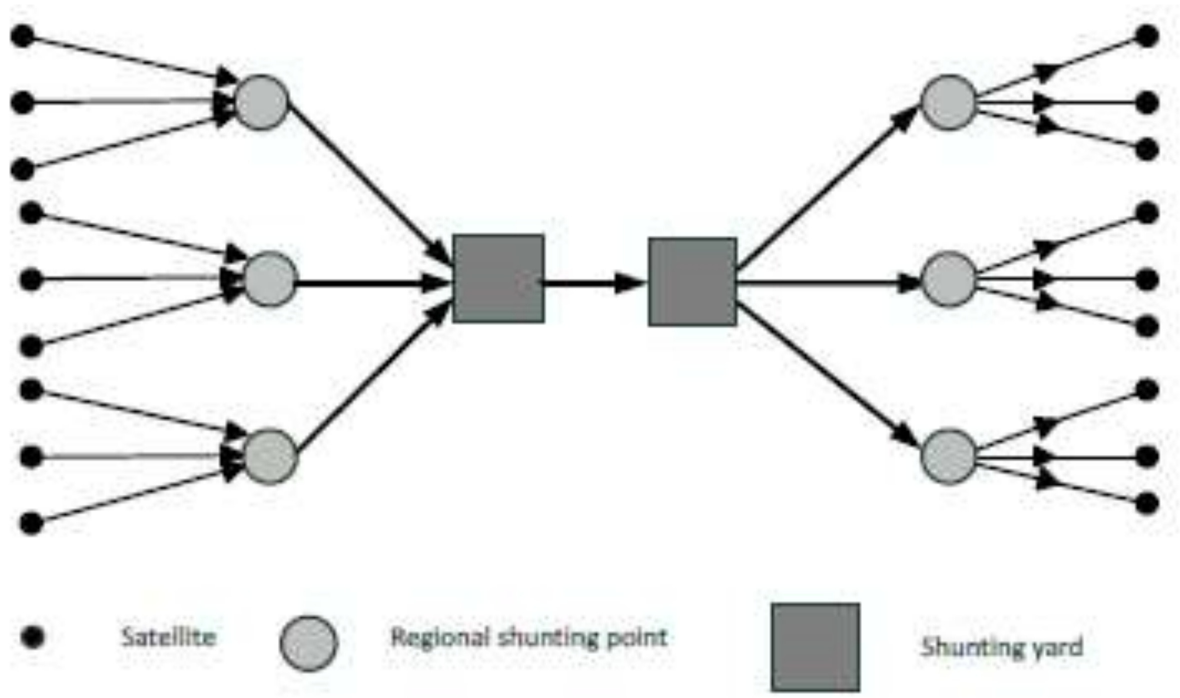
To remain competitive against road transport, SWL has to cover even under these boundary conditions all national relations in Switzerland in an overnight service. To meet this requirement, the production system must be continuously improved. Additionally, the shunting processes have to be optimised and shortened by technical innovations, so that the flexibility and punctuality of SWL can be increased.

To increase the competitiveness of SWL compared to road transport an optimisation of the production schemes is necessary. The main goal is to increase the quality of SWL and the reduction of production costs. Here the following approaches shall be used to improve cost efficiency on the network:

- Increase of the utilization of trains – to reduce the number of trains,
- Stabilization of the train occupancy,
- Reduction of the deviation of wagons,
- Enhancement of the supplied services by shorter transport times.

Nowadays, most of the European railways use a modified hub-and-spoke-system for their SWL production schemes (Bruckmann 2007). In Switzerland, the SWL production scheme consists of a three stage collection and distribution system. The first stage consists of the satellites including the sidings where the wagons origin and destinate. The second stage are the regional production points (in German Regionale Cargo Produktion or RCP teams as they will be referred as from now on) where the trains for the shunting yards are formed and as a third stage the shunting yards themselves.

Figure 17: SWL network structure



Source: IVT

By dividing the production schemes in their segments, three approaches for an optimisation of SWL can be identified:

- Optimisation of the train operation on the lines (between the shunting points);
- Optimisation of the shunting processes;
- Optimisation of the network structure.

IVT suggests an optimisation on the train operations or the production schemes in the following pages. A simulation tool called WagonSim has been developed based on an existing tool called MATSim to simulate the Swiss SWL network and generate different scenarios that might improve the overall efficiency of the network.

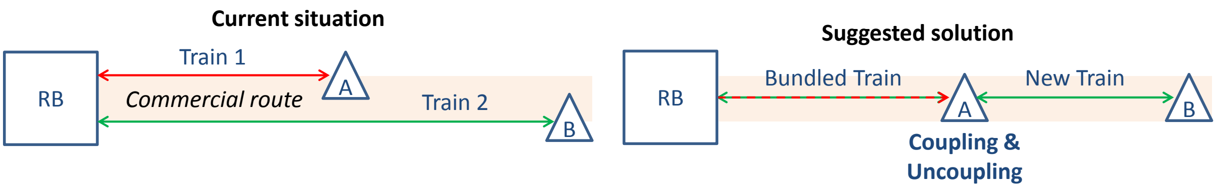
3.3 Suggestion for improvement (general ideas and cases)

Taking into account the previous description of the SBB Cargo SWL network, ETHZ developed a suggestion of improvement. Respecting the existing commercial routes, shunting yards and RCP team locations, ETHZ suggests to reorganize the traffic by bundling existing trains that have the same shunting yard origin (or destination) and that share part of their commercial route. This idea comes from the fact that SWL trains usually do not reach the maximum length allowed in a rail section (maximum train length is 750 m in most of the Swiss rail sections, but SWL trains are usually no longer than 450

m) and therefore there is room available for increasing the ratio of wagons transported by locomotive in a same slot. The aim is to reduce costs and also reduce need of slots leading to a more efficient use of the resources.

For instance, an existing situation in the SBB Cargo SWL network is depicted on Figure 18. There is a set of trains shipping wagons between one shunting yard (noted RB as a shortcut from its German name "Rangierbahnhof") and some RCP (A and B for this example) located in the same commercial route. ETHZ suggests to bundle these trains until the first RCP (A), and then couple (or uncouple, depending on the direction) the wagons that need to travel further, allowed them to be shipped in a second train that runs between this RCP (A) to the next one (B). A priori, this solution provides a less dense schedule in the line from RB to RCP A and less kilometres run by the locomotives.

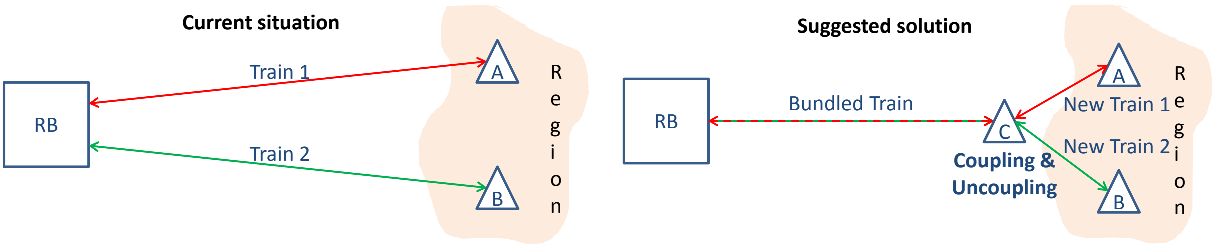
Figure 18: Today's SWL production scheme versus suggested solution



Source: IVT

Another case would be a set of trains shipping wagons between a shunting yard and RCP located in the same region. In that case (see Figure 19), the suggested solution by ETHZ is to bundle the trains running from and to that region, and split them in the last (or first) station located on the shared route which is equipped for that kind of operations. After that, the new trains are shipped from that station to the RCP that wait for the shipment. The potential benefits from this solution are on the lines of the previous example. Bundling part of the route of train 1 and train 2 decreases the demand for slots on the network, and only one locomotive is required for that part of the journey. From the C point on, the second locomotive is required, but the overall kilometres done by the locomotives should be smaller. Thus, operational costs should be smaller.

Figure 19: Today's SWL production scheme versus suggested solution



Source: IVT

Furthermore, it is intended to run these bundled trains three times per day in each direction (main shunting yard – RCP, and vice versa), so the demand can be served every six hours during the day (at 6.00 a.m., 12.00 p.m. and 18.00 p.m. approximately). This approach is similar to the one being currently developed by SBB Cargo, although their concerns are mostly focused on the current waiting times, queues and delays that occur on the shunting yards due to a single shunting peak per day. They are considering three picks of shunting per day instead, so the operation flow is more constant and the probability of overloading the station is lower.

3.4 Introduction to the software (MATSim and WagonSim)

3.4.1 MATSim

IVT modeled the SBB Cargo SWL network in Switzerland. A program called wagonSim has been developed specifically for that purpose. The model is built as an agent-based simulation on MATSim basis. MATSim follows an activity based approach for traffic simulation as described in (Balmer et al., 2008). The general approach of MATSim is iterative: starting from an initial condition, the system optimises the behaviour of the agents. The experiences of the agents in former simulations are considered in the following ones.

For generating a MATSim model first a population of agents with their activities is needed. For each agent, based on these activities, a schedule is defined. The schedule includes e.g. the number and type of activities, the sequence, the starting and ending time of the activities, their mode choice and their route choice and the grouping of agents travelling together.

Additional already existing traffic flow simulations are available for MATSim including public transport (Rieser 2010). In public transport the main parameters are the buses (or trams) which are driving on fixed lines with a schedule and a set of stops having a maximum capacity. If the demand is higher than the capacity the passengers the last passengers entering a bus are left on the bus-stop (first-in first-out).

3.4.2 WagonSim

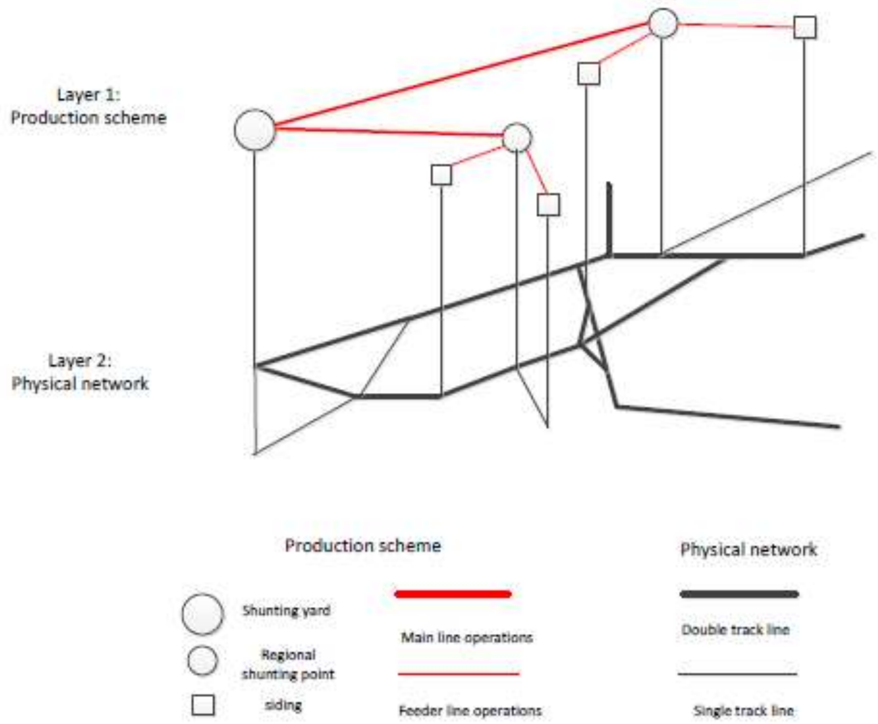
Agent-based approaches to freight simulation were already considered (Kavicka et al., 2007) on an ABASim basis. The MATSim approach is also used for freight transportation modeling. A MATSim approach for a network optimisation is not considered. Even a real-world application of MATSim for freight purposes is not known till now.

For modeling the SWL network in wagonSim, the MATSim approach has to be adapted to the needs of the SWL. Therefore, a specific modeling of the network, the schedules and the agents is required. As a first step, the existing timetable has been transferred into the MATSim database. The modeling approach is as open as possible to allow further steps of an automatic network and timetable generation. In the first model which has been already developed, some restrictions according to the data availability had to be accepted.

In a second step, one day in the existing SWL network in Switzerland has been modeled. Therefore each part of the SWL system has to be depicted in MATSim: The demand, the schedule of the trains including the infrastructure network and the shunting processes. Some additional parts of the model are already implemented but not used yet.

To evaluate the effects of optimisations in a SWL network, a suitable simulation tool is needed, which can model all required aspects of the single wagon traffic. The aim of the tool is to model the routing of the freight wagons according to the routes in the real SWL network. Therefore modeling of both network layers of SWL is required.

Figure 20: Network layers



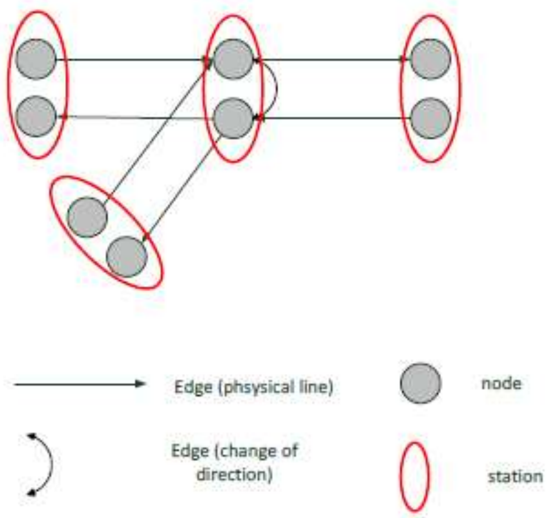
Source: IVT

The first layer describes the physical infrastructure with its capacities and the available train routes. The capacities of the infrastructure network are restricted by the number of available train paths for freight trains. In Switzerland there is an integral fixed-interval timetable. For the freight trains a fixed number of train paths is reserved in a standard hour. In the peak hour of the passenger transport, this number of train paths is reduced due to extra trains. For the generation of new schedules and for an automatic train routing on the network, these restrictions have to be considered.

The second layer is the production network. In concrete terms this means the assignment of the access points (sidings) to regional shunting points and shunting yards. The production network includes also the train schedules and the commercial stops of the trains at the stations, where a pick-up and set-down of wagons is possible.

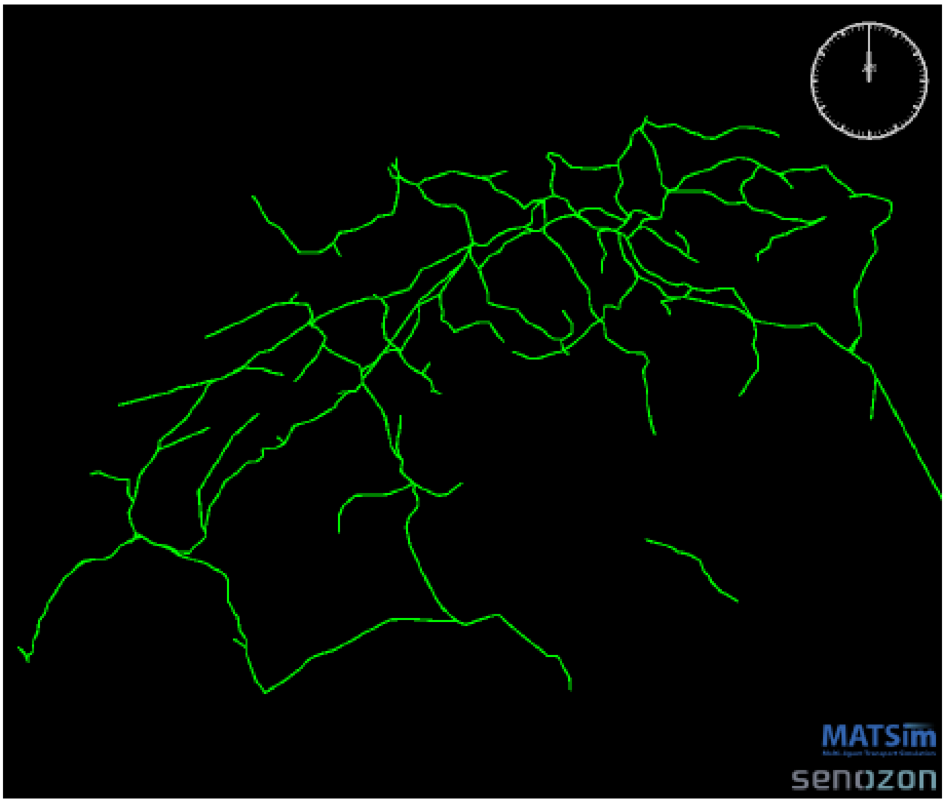
The wagonSim model contains both network layers – the physical infrastructure and the production schemes, which includes the schedule and the demand. The physical infrastructure is modeled as a graph containing nodes and edges. The nodes are representing the stations and junctions, the edges are the lines between the nodes. The edges contain information about their length, the maximum speed of the trains, a maximum capacity, the maximum train length and train weight. These constraints are available e.g. for automatic scheduling. To model the constraints on junctions, the edges are directed. The extra time needed for a change in the direction of travel can be modeled by an additional edge representing the time needed.

Figure 21: Model of the infrastructure network (example with split up of two lines)



Source: IVT

Figure 22: Actual Swiss SWL production network in MATSIM

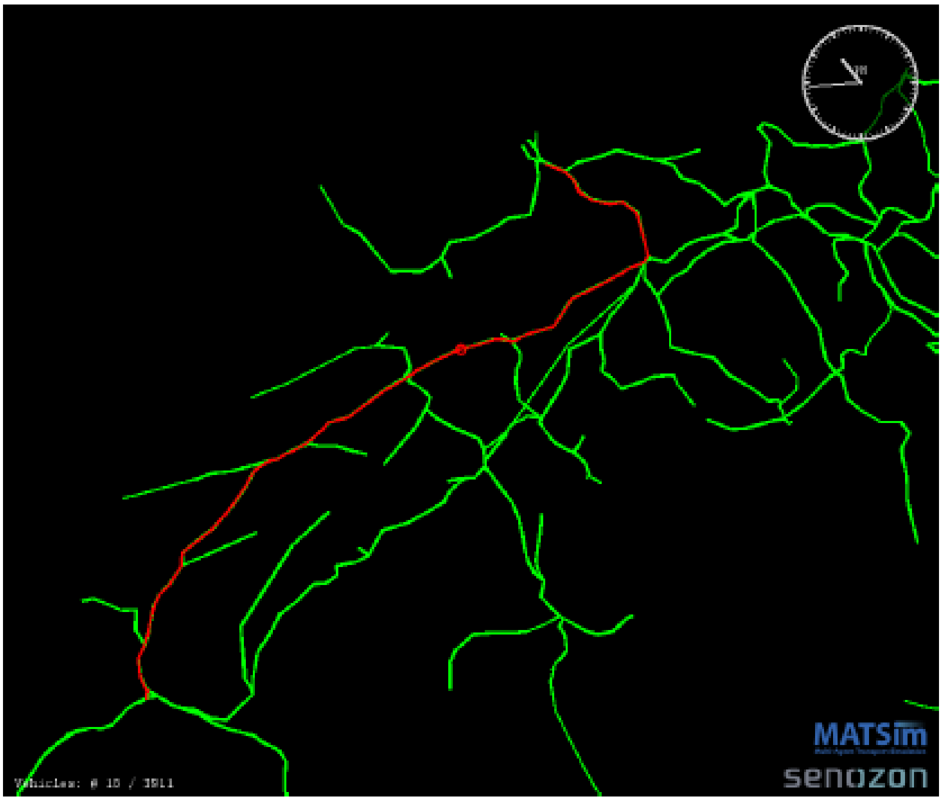


Source: IVT

The first element of the production scheme model is the demand. For the model the demand data for the SWL network in Switzerland for one day was used. Each wagon transported during this day was considered as one single agent with an origin and a destination. The starting time at the origin was set fixed to 2 p.m. as no data about this were available. In later versions of the model, the demand can be depicted with a specific origin time for each wagon in each siding. To model capacity constraints on the trains each wagon has a length and a gross weight.

The second part is about the schedule of the trains. Each train (or group of trains with the same origin, destination and commercial stops) is modelled as one public transport line. Each line has one dedicated type of vehicle (locomotive) with a specific maximum speed, a maximum train length and maximum train weight. So on the commercial stops wagons can board until the maximum train length or the maximum train weight is reached. If the number of wagons on a stop exceeds the capacity of a train, the wagons will be left on the station.

Figure 23: Fixed routing of a train with one intermediate stop



Source: IVT

To calculate the network-load of the infrastructure network, in a next step the trains of the production network were routed on the optimal path. In the current model only the travel times are used as routing criteria. For the calculation of travel times, the model considers the length of the edge, the average speed of the trains and the time for changing the locomotive, when the train changes the direction of travel. The infrastructure model has an open design, so that in further steps additional criteria like capacity restraints (e.g. caused by the availability of train paths) can be integrated in the routing algorithm.

The third part is the modelling of the shunting. To simulate the shunting time, a wagon, which arrives on a station, will be stored in a shunting loop for a specific time. The maximum shunting capacity (wagons per hour) is modelled by a capacity restraint on this loop. The shunting time and capacity depends of the type of station. So shunting with locomotives has a shorter shunting time and a small capacity. Shunting yards with a hump have a large capacity but also a longer shunting time.

For the routing of the wagon the existing iterative MATSim routing algorithm is used. So in the first iteration some of the wagons do not reach their destination due to the capacity constraints on the networks. So several optimisation loops will be done. In each loop 20 percent of the wagons are rerouted on a new optimal route. This optimisation routine will continue until each wagon has found a possible route or there is a stable solution with wagons which do not find a suitable route.

The results of the simulation apply in an events file, which contains all events during the simulation. In general all necessary data analysis can be done on basis of this events file using java or standard statistic software. To extract important characteristics in a short time the SENOZON-tool Via is used. This tool also allows a time dynamic visualization.

Additional information about the wagonSim can be found in the annex.

3.4.3 Data preparation

3.4.3.1 Infrastructure

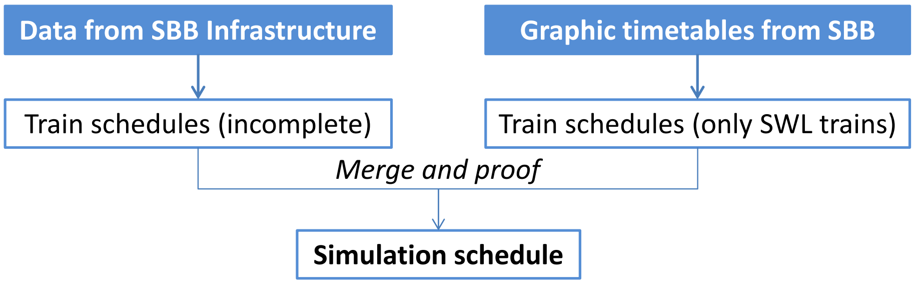
SBB Infrastructure provided data to IVT to model the SWL network. The data provided include information about stations, wagons, locomotives and schedules. Part of this data was implemented by SENOZON to the wagonSim model to create the layer that represents the infrastructure of the network. The data contained the name and code of the stations, and their coordinates. This information was used to build up the nodes of the network and the tracks that connect those stations were approximated by connecting the nodes in straight lines. The density of nodes on the network is high enough to offer a realistic approximation of the infrastructure network.

3.4.3.2 Schedules

The schedules used for the simulations are a result of a combination of data provided by SBB Infrastructure to IVT and the SBB graphic timetables (see Figure 24). It was needed to use the second data set because the data provided to IVT was incomplete. When the first test of the model was executed by IVT only using SBB Infrastructure schedule, several stations on the model were not served by SWL trains. Therefore it was decided to use another data source, e.g. SBB graphic timetables (available in pdf format on the website). Unfortunately extracting the data from the SBB graphic timetables was not an easy task and it caused delays on the development of WP 6. The SBB graphic timetables include all trains run by SBB. It was then needed to identify which trains were shipping

SWL, using the train codes. Moreover, due to the big amount of trains it was needed to create an algorithm that will convert the pdf into usable excel data.

Figure 24: Generation of the simulation schedule



Source: IVT

3.5 Simulation and results

3.5.1 Introduction

IVT modelled the current SWL schedule of SBB Cargo on the Swiss rail network of SBB using de modelling tool MATSim. The data used for this simulation was provided by SBB Cargo. MATSim works as an agent-based engine that seeks for the best routing of each of its agents in favour of an overall network performance though iterations. In order to quantify the performance of the production scheme modelled, IVT selected the following KPIs: train-kilometres; train-hours; wagon-kilometres; wagon-hours and tonne-kilometres.

When simulating the original schedule of SBB Cargo from 2012, with a total of 4,100 wagons in the system, the KPIs take the following values:

Table 3: KPI values on the current schedule of SBB Cargo

Train kilometres	Train hours	Wagon kilometres	Wagon hours	Tonne-kilometres
10,2896	2,463	40,1519	68,378	15,546,472

Source: IVT

Furthermore, it needs to be taken into account that even though there are about 4,100 wagons in the system, some of them do not reach their final destination during the simulations (referred here as "stuck wagons"). Moreover some of them do not even get into a train, therefore the so called group "transported wagons" makes reference to those that indeed are at least partially transported although might not get to the intended final destination during the simulation". Some of these events are due to the fact that data is not complete and sometimes it does not match the schedule data with the infrastructure data. Some other of these events take place due to the fact that the simulation represents 72 hours schedule but some wagons might need to wait longer due to transhipments.

Besides modelling the current SWL schedule of SBB Cargo, IVT also conceived 6 modifications of the current schedule (cases) based on the concept explained in Chapter 3.3. Each of these cases targets a specific area or line of the network (see Table 4 and Figure 25). The goal is to evaluate the impact this local changes have on the overall performance of the network. For each simulation, the results are evaluated using the KPIs above mentioned. The values of Table 3 are used as a baseline to decide whether a case improve the current performance of the network.

To simulate each case the following steps have been carried out:

- All trains that run service between the selected shunting yard and the selected RCP teams in any direction have been indentified in the current schedule.
- Substitution of these trains for a service of 3 trains per day in each direction that run without intermidiate stops between the shunting yard and the RCP teams, allowing coupling and decoupling activities when needed.
- Creation of a new schedule that include this changes and keeps the previous services in the other parts of the network.

3.5.2 The cases

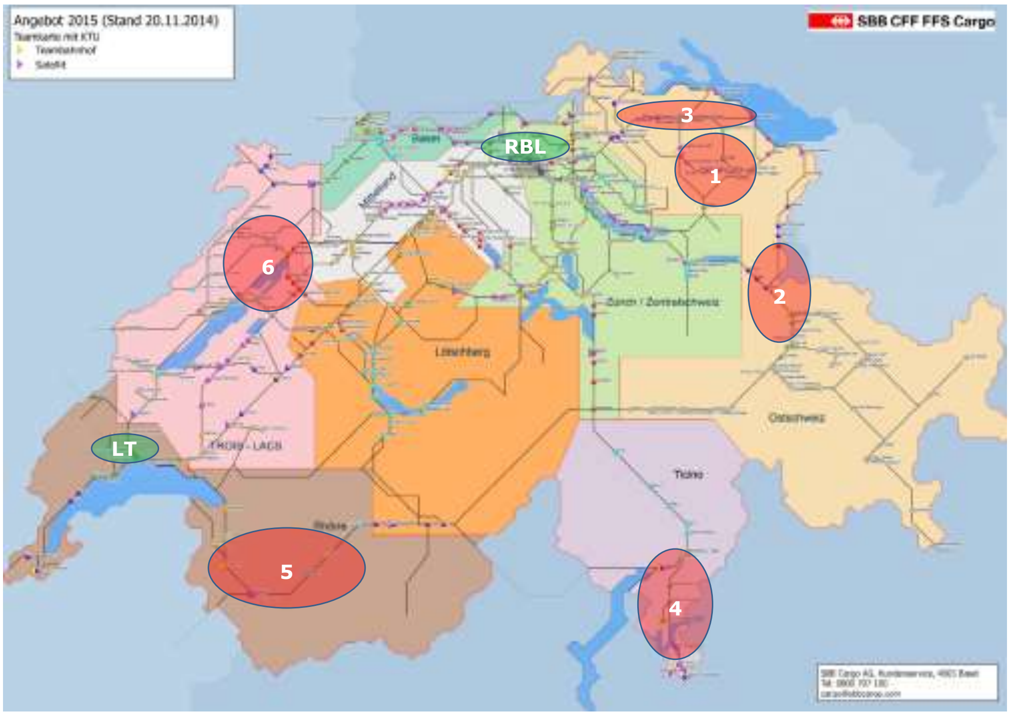
In Table 4, the cases that IVT simulated on MATSim as variations of the current production scheme are displayed. Each case modifies the shipping relationship between a shunting yard and RCP-team stations. In Figure 25, the exact location of these RCP-teams is indicated with numbered red cercles on the Swiss SWL network map. The 2 shunting yards of Table 4 are also indicated in Figure 25 in green cercles and their initials.

Table 4: Test cases developed by IVT to study possible changes on the production scheme of SBB Cargo SWL network

<table>
<tr><th></th><th>Shunting yard</th><th>RCP-team station</th><th colspan="2">New Shunting yard –RCP service</th></tr>
<tr><td rowspan="2"></td><td rowspan="2">RBL - Limmatal</td><td>WIL - Wil</td><td colspan="2" rowspan="2">RBL - WIL (coupling & uncoupling) - GSS</td></tr>
<tr><td>GSS - Gossau</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">RBL - Limmatal</td><td>BU - Buchs SG</td><td rowspan="2">RBL - SASL Sargans (coupling & uncoupling) -</td><td>SASL - BU</td></tr>
<tr><td>LQ - Landquart</td><td>SASL - LQ</td></tr>
<tr><td rowspan="3">3</td><td rowspan="3">RBL - Limmatal</td><td>FF - Frauenfeld</td><td colspan="2" rowspan="3">RBL - FF (coupling & uncoupling) - WF (coupling & uncoupling) - RH</td></tr>
<tr><td>WF - Weinfelden</td></tr>
<tr><td>RH - Romanshorn</td></tr>
<tr><td rowspan="3">4</td><td rowspan="3">RBL - Limmatal</td><td>BEL - Bellinzona</td><td colspan="2" rowspan="3">RBL - BEL (coupling & uncoupling) - CD (coupling & uncoupling) - LGV</td></tr>
<tr><td>LGV - Lugano Vedeggio</td></tr>
<tr><td>CD - Cadenazzo</td></tr>
<tr><td rowspan="3">5</td><td rowspan="3">LT - Lausanne</td><td>MA - Martigny</td><td colspan="2" rowspan="3">LT - SM (coupling & uncoupling) - MA (coupling & uncoupling) - SIO</td></tr>
<tr><td>SM - St-Maurice</td></tr>
<tr><td>SIO – Sion</td></tr>
<tr><td>6</td><td>LT - Lausanne</td><td>FRI - Fribourg</td><td colspan="2">LT - ROM (coupling & uncoupling) - FRI</td></tr>
</table>

Source: IVT

Figure 25: SBB Cargo SWL network including locations of test cases



Source: SBB Cargo, modified by IVT

The results of the simulation for each case are presented, together with the results of the simulation of the original schedule, as it follows:

Table 5: KPI values on the current schedule of SBB Cargo and in the test cases

	Original	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Stuck wagons	22.59%	21.37%	23.56%	22.98%	23.20%	21.67%	22.85%
Transported wagons	97.41%	97.43%	97.44%	97.27%	97.44%	97.95%	97.44%
Train kilometres	102,896	103,076	99,556	102,761	104,835	96,778	103,078
Train hours	2,463	2,460	2,436	2,478	2,504	2,285	2,465
Wagon kilometres	401,519	385,654	355,677	381,919	384,367	397,882	407,316
Wagon hours	68,378	68,004	68,381	66,833	68,296	69,901	66,723
Tonne kilometres (in millions)	15.5465	14.8739	13.6679	14.6991	14.7070	15.3026	15.6402

Source: IVT

Analysing the results it is stated that most of the KPIs improve the current situation (compare Table 6). The negative values indicate that the KPI has been reduced, which means less kilometres or travel time per train or wagon, depending on the KPI. Thus, these results indicate an improvement in efficiency of the network and use of resources.

Table 6: KPI percentage values of the test cases with respect to the current schedule of SBB Cargo

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Stuck wagons	-5.40%	4.32%	1.73%	2.70%	-4.06%	1.19%
Transported wagons	0.02%	0.03%	-0.15%	0.03%	0.55%	0.03%
Train kilometres	0.17%	-3.25%	-0.13%	1.88%	-5.95%	0.18%
Train hours	-0.13%	-1.08%	0.61%	1.68%	-7.22%	0.08%
Wagon kilometres	-3.95%	-11.42%	-4.88%	-4.27%	-0.91%	1.44%
Wagon hours	-0.55%	0.00%	-2.26%	-0.12%	2.23%	-2.42%
Ton-kilometres	-4.33%	-12.08%	-5.45%	-5.40%	-1.57%	0.60%

Source: IVT

Table 7: Wagon kilometres and wagon hours divided by wagons transported

	Original	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Wagon kilometres	100.53	96.87	89.03	95.77	96.21	101.76	101.96
Wagon hours	17.12	17.08	17.12	16.76	17.10	17.88	16.70

Source: IVT

Table 8: Wagon kilometres and wagon hours divided by total wagons

	Original	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Wagon kilometres	97.93	94.38	86.75	93.15	93.75	99.67	99.35
Wagon hours	16.68	16.64	16.68	16.30	16.66	17.51	16.27

Source: IVT

Case 1: Modification of the line RB Limmatal – Wil – Gossau

The service along this line has been modified by substituting trains shipping SWL between RBL and Wil and trains shipping SWL between RBL and Gossau, by trains that bundle the service between RBL and Wil, and then between Gossau and Wil. Modifications can be found in Table 9.

Table 9: Modification of the timetable for Case 1

Trains removed	Trains added
62907 RBL – GSS 03:10	62907 RBL – GSS 03:10
62923 RBL - GSS (+SGWI + SGBR) 07:49	62923 RBL - GSS (+SGWI + SGBR) 07:49
62950 (SGGB + SGW + SGBR + SGWI) GSS – RBL 13:51	62950 (SGGB + SGW + SGBR + SGWI) GSS – RBL 13:51
62978 (SGGB + SGW + SGBR + SGWI) GSS – RBL 17:14	62978 (SGGB + SGW + SGBR + SGWI) GSS – RBL 17:14
62982 GSS – RBL 20:04	62982 GSS – RBL 20:04

Source: IVT

Simulation results show that the overall situation improves. The number of stuck wagons reduces in 5.40%, meaning that travel time of certain wagons is reduced and they reach their destination during the simulation (72 hours), which may be because of more direct trains or reduced transhipment time. The transported wagons stay almost the same (0.02%). Train-kilometres and wagon-kilometres stay more or less the same (0.17% and -0.13%), as the locomotives do similar routes and the same number of trains are added and removed. Wagon-kilometres reduce quite significantly which implies that wagons follow a more efficient schedule, also reflected on the reduction of Wagon-hours (0.55%) and the big reduction of tonne-kilometres (4.33%). Moreover, the wagon-kilometres and wagon-hours divided by wagons transported (Table 7) and by total wagons (Table 8) are also reduced; therefore the efficiency of the movements of the wagons increases.

3.5.2.1 Case 2: Modification of the line RB Limmatal – Sargans - Buchs SG and Landquart

The service along this line has been modified by substituting trains shipping SWL between RBL and Buchs SG and trains shipping SWL between RBL and Landquart, by trains that bundle the service between RBL and Sargans, and then adding trains shipping SWL between Sargans and Buchs SG, and trains shipping SWL between Sargans and Landquart. Modifications can be found in Table 10.

Table 10: Modification of the timetable for Case 2

Trains removed	Trains added
50236 (+ZIZS) LQ – SA – RBL (+ 19 stations afterwards) 10.32	20101 RBL – SA 06:00
63315 RBL – SA – LQ 03.51	20103 RBL – SA 12:00
63352 (+CH +ZIZS) LQ – SA – RBL 11.57	20105 RBL – SA 18:00
63368 (+CH +ZIZS) LQ – SA – RBL 16.40	20102 SA – RBL 07:48
60305 RBL – SA – SASL – BU 00.33	20104 SA – RBL 13:48
60377 RBL – SA – SASL – BU 18.27	20106 SA – RBL 19:48
60382 BU – SASL – SA – RBL 19.23	20201 SA – LQ 07:22
60383 RBL – SA – SASL – BU 21.34	20203 SA – LQ 13:22
	20205 SA – LQ 19:22
	20202 LQ – SA 06:00
	20204 LQ – SA 12:00
	20206 LQ – SA 18:00
	20301 SA – BU 07:22
	20303 SA – BU 13:22
	20305 SA – BU 19:22
	20302 BU – SA 06:00
	20304 BU – SA 12:00
	20306 BU – SA 18:00

Source: IVT

Simulation results show (see Table 6) that the number of stuck wagons increases (4.32%), see Table 6, which might be explained by the fact that along the service of the trains removed they were serving intermediate stations between RBL and the RCP teams, which should not be done in that way, but by last-mile hybrid locomotives instead. This fact might also explain the big drop in KPIs such as wagon-kilometres and tonne-kilometres (-11.42% and -12.08%), see Table 6. The number of wagons transported (0.03%) is similar to the original scenario, which combined with the increase of stuck wagons indicates that some of the travelling wagons do not reach their destination point.

On the other hand, the wagon-kilometres and wagon-hours divided by wagons transported (Table 7) are reduced which might indicate an increase of efficiency or also be related to the fact that more wagons do not reach their destination point and therefore travel less hours and less kilometres.

3.5.2.2 Case 3: Modification of the line RB Limmatal – Frauenfeld - Weinfelden - Romanshorn

The service along this line has been modified by substituting trains shipping SWL between RBL and Frauenfeld, trains shipping SWL between RBL and Weinfelden, and trains shipping SWL between RBL and Romanshorn, by trains that bundle the service between RBL and Frauenfeld, then between Frauenfeld and Weinfelden, and finally between Weinfelden and Romanshorn. Modifications can be found in Table 11.

Table 11: Modification of the timetable for Case 3

Trains removed	Trains added
62817 RBL - FF - WF - RHW - RHVL – RHS 05.20	30001 RBL - FF - WF - RHW - RHVL – RHS 06:00 (10 min stop at FF, 10 min stop at WF)
62854 RHS – RHVL – RHW – WF – FF – RBL 11.21	30003 RBL - FF - WF - RHW - RHVL – RHS 12:00 (10 min stop at FF, 10 min stop at WF)
62888 (+SMG, RCK, FTAA, STA, RS, RSHF, HN, STCH, ARB, ARBS, EGN) RHS – RHVL – RHW – WF – FF – RBL 19.34	30005 RBL - FF - WF - RHW - RHVL – RHS 18:00 (10 min stop at FF, 10 min stop at WF)
62811 RBL - FF – WF 04.00	30002 RHS – RHVL – RHW – WF – FF – RBL 06:00 (10 min stop at WF, 10 min stop at FF)
62867 RBL - FF – WF (+WFKV, BGL, SLG) 15.06	30004 RHS – RHVL – RHW – WF – FF – RBL 12:00 (10 min stop at WF, 10 min stop at FF)
62876 (+BGL, WFKV) WF – FF - RBL 18.32	30006 RHS – RHVL – RHW – WF – FF – RBL 18:00 (10 min stop at WF, 10 min stop at FF)
62880 WF – FF - RBL 17.32	

Source: IVT

Simulation results show (see Table 6) that the number of stuck wagons increases a little bit (1.73%) and the transported wagons almost stay the same (-0.15%), probably for the similar reasons that applied for Case 2: small stations not served due to the change of the schedule. On the other hand most of the KPIs improve, the most outstanding improvements are on reduction of wagon-kilometres, wagon-hours and tonne-kilometres (-4.88%, -2.26% and -5.45%), thus improving the overall efficiency of the network. Furthermore, the average wagon-kilometres and wagon-hours per wagon transported also decrease (see Table 7).

3.5.2.3 Case 4: Modification of the line RB Limmatal - Bellinzona - Lugano Vedeggio - Cadenazzo

The service along this line has been modified by substituting trains shipping SWL between RBL and Bellinzona, trains shipping SWL between RBL and Lugano Vedeggio, and trains shipping SWL between RBL and Cadenazzo, by trains that bundle the service between RBL and Bellinzona, then between Bellinzona and Lugano Vedeggio, and finally between Lugano Vedeggio and Cadenazzo. Modifications can be found in Table 12.

Table 12: Modification of the timetable for Case 4

Trains removed	Trains added
60124 (CHI + another 9 stations) LG - BEL – RBL 00.17 60152 (CHI + another 9 stations) LG - BEL - RBL 08.58 62796 (CHI + another 9 stations) LG - BEL - RBL 18.14 Note: there are currently no trains travelling in the opposite direction.	40101 LG - BEL – RBL 06:00 (10 min stop at BEL) 40103 LG - BEL – RBL 12:00 (10 min stop at BEL) 40105 LG - BEL – RBL 18:00 (10 min stop at BEL) 40102 RBL - BEL – LG 06:00 (10 min stop at BEL) 40104 RBL - BEL – LG 06:00 (10 min stop at BEL) 40106 RBL - BEL – LG 06:00 (10 min stop at BEL) 40201 BEL – CD 06:41 40203 BEL – CD 12:41 40205 BEL – CD 18:41 40202 CD – BEL 09:11 40204 CD – BEL 15:11 40206 CD – BEL 21:11

Source: IVT

Analogue to the above, simulation results show (see Table 6) that the stuck wagons increase by a small amount (2.70%) and the transported wagons almost stay the same (0.03%), most likely for the similar reasons that applied for Case 2 and 3. The KPIs train-kilometres and train-hours also increase (1.88% and 1.68%), which might be because there are more trains added than removed in this case. This is due to the absence of service in the direction from the RCP-teams to RBL on the original schedule that has been included on the schedule of case 3. The results also show that the KPIs wagon-kilometres, wagon-hours and tonne-kilometres decrease (-4.27%, -0.12% and -5.40%). These results indicate that this solution is also improving the efficiency of the network, at least partially, in terms of movement of wagons. Finally, Table 7and Table 8 also show that average wagon-kilometres and wagon-hours per wagon also decrease.

3.5.2.4 Case 5: Modification of the line RB Lausanne Triage - Martigny - St-Maurice – Sion

The service along this line has been modified by substituting trains shipping SWL between RB Lausanne Triage and Martigny, trains shipping SWL between RB Lausanne Triage and St-Maurice, and trains shipping SWL between RBL and Sion, by trains that bundle the service between RB Lausanne Triage and Martigny, then between Martigny and St-Maurice, and finally between St-Maurice and Sion. Modifications can be found in Table 13.

Table 13: Modification of the timetable for Case 5

Trains removed	Trains added
47626 (+ 21 stations) SIO - MA - SM - LS (+ 18 stations) 09.07	62907 RBL – GSS 03:10
47639 (+ 13 stations) LS - SM - MA - SIO (+ 16 stations) 14.00	51001 LS - SM - MA – SIO 06:00 (10 min stop at SM, 10 min stop at MA)
50103 (+ 5 stations) LS - SM - MA - SIO (+ 13 stations) 01.57	51003 LS - SM - MA – SIO 12:00 (10 min stop at SM, 10 min stop at MA)
50177 SIO - MA - SM - LS (+ 3 stations) 19.57	51005 LS - SM - MA – SIO 18:00 (10 min stop at SM, 10 min stop at MA)
50195 (+ 5 stations) LS - SM - MA - SIO 21.40	51002 SIO - MA - SM – LS 06:00 (10 min stop at MA, 10 min stop at SM)
60591 (+ 10 stations) SIO - MA - SM - LS 17.14	51004 SIO - MA - SM – LS 12:00 (10 min stop at MA, 10 min stop at SM)
60785 (+ 13 stations) SIO - MA - SM - LS (+ LOTS of stations) 17.38	51006 SIO - MA - SM – LS 18:00 (10 min stop at MA, 10 min stop at SM)
61211 (+ 7 stations) LS - SM - MA - SIO (+ 13 stations) 02.45	
61215 (+ 7 stations) LS - SM - MA - SIO 03.54	
61219 (+ 7 stations) LS - SM - MA - SIO (+ 7 stations) 04.22	
61223 (+ 7 stations) LS - SM - MA - SIO (+ 13 stations) 05.04	
61227 (+ 7 stations) LS - SM - MA - SIO (+ 3 stations) 06.37	
61244 (+ 10 stations) SIO - MA - SM - LS (+ 6 stations) 10.44	
61262 (+ 3 stations) SIO - MA - SM - LS (+ 6 stations) 15.00	
61266 (+ 7 stations) SIO - MA - SM - LS (+ 6 stations) 15.29	
61284 (+ 13 stations) SIO - MA - SM - LS (+ 6 stations) 19.41	
61288 SIO - MA - SM - LS (+ 6 stations) 20.33	

Source: IVT

Here the results show a considerable decrease of stuck wagons (see Table 6) (-4.06%) and a small increase of transported wagons (0.55%). These two facts imply that the schedule of Case 5 is more efficient in terms of wagon delivery, because it does not only increase the transported wagons but it also achieves to deliver more wagons into their final destination within the 72 simulated hours of schedule. Moreover most of the KPIs improve. The biggest gains are on the train-kilometres and train-hours (-5.95% and -7.22%), probably due to the number of trains removed is more than double than the trains added.

On the other hand, the average wagon-kilometres and wagon-hours per wagon transported and total number of wagons increase a bit (see Table 7 and Table 8), which can be explained since the stuck wagons are reduced and therefore several wagons travel longer in time and space because they reach their final destination.

3.5.2.5 Case 6: Modification of the line RB Lausanne Triage – Fribourg - Romont

The service along this line has been modified by substituting trains shipping SWL between RB Lausanne Triage and Fribourg and trains shipping SWL between RBL and Romont, by trains that bundle the service between RB Lausanne Triage and Fribourg, and then between Romont and Fribourg. Modifications can be found in Table 14.

Table 14: Modification of the timetable for Case 6

Trains removed	Trains added
50006 (+ loads of extra stations) FRI - ROM - LS (+ loads of extra stations) 00.17	60001 LS - ROM - FRI 06:00 (10 min stop at ROM)
50093 (+ loads of extra stations) LS - ROM - FRI (+ loads of extra stations) 22.53	60003 LS - ROM - FRI 12:00 (10 min stop at ROM)
50188 (+ loads of extra stations) FRI - ROM - LS (+ loads of extra stations) 21.43	60005 LS - ROM - FRI 18:00 (10 min stop at ROM)
50189 (+ loads of extra stations) LS - ROM - FRI (+ loads of extra stations) 22.19	60002 FRI - ROM - LS 06:00 (10 min stop at ROM)
50190 (+ loads of extra stations) FRI - ROM - LS (+ loads of extra stations) 21.28	60004 FRI - ROM - LS 12:00 (10 min stop at ROM)
61607 (+ loads of extra stations) LS - ROM - FRI (+ loads of extra stations) 02.05	60006 FRI - ROM - LS 18:00 (10 min stop at ROM)
61617 (+ loads of extra stations) LS - ROM - FRI (+ loads of extra stations) 05.26	
61642 (+ loads of extra stations) FRI - ROM - LS (+ loads of extra stations) 19.42	
61664 FRI - ROM - LS (+ loads of extra stations) 17.35	
61674 FRI - ROM - LS (+ loads of extra stations) 18.45	

Source: IVT

The stuck wagons increase a bit (1.19%), the transported wagons minimally (0.03%). Again, the small increase in stuck wagons might be due to the trains removed that might have been serving small intermediate stops between the shunting yard and the RCP-team stations and that now are not served with the trains added. On the other hand, the KPIs related to train-kilometres and train-hours keep quite stable (0.18% and 0.08%), and the ones related to the wagons vary a little, e.g., wagon-kilometres 1.44% and wagon-hours -2.42%.

Table 7and Table 8 indicate that the average wagon-kilometres and wagon-hours per wagon transported and total number of wagons keep quite stable, increasing a bit the distance related and decreasing a bit the time related. Therefore, with a lower number of trains a similar behaviour of the overall network is achieved.

4 Summary and Conclusions

Swiss Split is a product of SBB Cargo that rates positively when compared with other SWL and last-mile business. Nevertheless it currently faces certain challenges. The life cycle of some of its wagons is coming to an end, the network where it operates is quite saturated and perspectives indicate a higher saturation of the network in the future. Furthermore, it also faces the inherent challenge of cost-efficiency business of the sector. For all these aforesaid reasons SBB Cargo seeks to improve its product.

To tackle the rolling stock challenge a special platform has been design and built within WP7. This platform will allow for using Sgnss wagons for the transport of sea containers from the terminals into the private sidings and proceed with the loading/unloading operations as it was done with the old Rs wagons. This platform will be a solution that will help to homogenize SBB Cargo rolling stock and will not add any extra cost or operation from the client point of view.

Regarding the network usage and the cost-efficiency challenges, IVT developed a simulation tool (wagonSim) that allows to simulate SWL production schemes. To test and validate the new software tool, different scenarios of the SBB Cargo SWL network (infrastructure and schedule) have been simulated and analysed. Thereby possible changes could be added to the current network so to improve its status. The software tool is based on an existing public transport model called MATSim which IVT has been working with for years. It is an iterative agent-based model that starting from an initial condition, the system optimises the behaviour of the agents. The experiences of the agents in former simulations are considered in the following steps and evaluations.

In order to develop the wagonSim model of the SBB Cargo SWL network (infrastructure and schedule), SBB Cargo provided some data to IVT. Although this data was not complete, IVT succeeded to simulate a simple model of the current network. This model has been used as a base line to develop new suggestions of improvements of the network.

A set of KPIs have been selected: Train-kilometres; Train-hours; Wagon-kilometres; Wagon-hours and Tonne-kilometres. These KPIs are used to evaluate either the current situation of the network and also the suggestions of improvements developed during the project. They are a quantitative reference to run rational comparison between different scenarios and allow the authors to evaluate the different options presented objectively.

Six different scenarios have been presented under the same idea of bundling certain train services that serve stations on the same region or commercial line. Although the scenarios are not optimal (none of them achieves to improve all the KPIs at the same time), they clearly point out that there is room for improvement in the current network. The suggestions presented are a recommended approach to follow if one is intended to improve the Swiss Split network.

5 References

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6 Annex

Overview

The wagonSim contribution is based on specialized input data. First it converts the input data into MATSim formats (scenario data). Second it allows one to manually adapt the scenario for different parameterization of train stops, shunting stations, minimum shunting times and dwell times of trains at stops. And third it sets up the configuration of the route optimization and runs the MATSim optimization cycle.

Glossary and Name Aliases

Since wagonSim uses the MATSim concepts to simulate and optimize routes for the demand some concepts and elements will be called and or used a bit different. The following names are used:

rail	a directed MATSim **link** of the transit network
train station / train stop	each **node** of the MATSim network represents a train station. The train stops itself are defined - as usual - as **transit stop facilities** connected to the incoming links of the node. Depending on the number of incoming links, resp. of the transit lines of the schedule a train station can have more than one transit stop facilities. But all of them have the same coordinate as the corresponding node.
locomotive	The locomotive is the MATSim **transit vehicle** that transports the agents. In this case each given locomotive has exactly one trip and therefore is part of a single **transit line** with a single **transit route** and a single departure. Each locomotive defines the **maximum length** and the **maximum weight** as capacity constraints while transporting wagons. Each locomotive is of MATSim vehicle type `dLT` (defaultLocomotiveType). In contrast to the standard MATSim transit locomotives will not be delayed because of entering and/or leaving agents. It stays very strictly to its schedule. The only delay that still can happen is because of "congestion" on rails. At last, each locomotive has a **defined travel speed per link** on its route. The speeds and the maximum length and weight is stored in an additional MATSim ObjectAttributes file called `transitVehicleAttributes.xml`.
wagon	A wagon is a MATSim **agent** (a MATSim **person**). Its demand consists of a single trip. Each wagon defines its **gross weight** and its **length** and are stored in an additional ObjectAttributes file called `wagonAttributes.xml`. The demand file is called `demand.wagons.xml`.
minimum shunting time	for each MATSim **transit stop** a minimum shunting time is defined. That's the time a wagon need to spend at least **when switching** locomotives. It is modeled as an additional `tranist_walk` where start and end is the egress transit stop. The value is stored in an additional table called `shuntingTimes.txt`.
shunting allowed	For each **locomotive** at each **transit stop facility** one can define if shunting is allowed. If not, no wagon can enter or leave the train. When shunting is not allowed, it does not mean that the train does not stop at that station. It can also wait for the time the schedule defines. To capture that behavior correctly the train drives on an additional **"dwell link"** for that time period.

Process Chain

wagonSim provides 5 process steps (where one of them is manual adaption) to create and run the MATSim routing optimization cycle. This allows one to enter the process chain at any step, if - for example - you want to use your own raw data format with your own data conversion process. The five process steps are:

A. **Schedule Data Conversion:** Based on well-defined but specialized input data formats the process converts the data into MATSim schedule, vehicle and network data formats with two additional data tables that can be (manually) adapted in process step B.
B. **Shunting Data Definition:** The two tables produced in step A can here be adapted to your needs. It defines shunting times and train stops where shunting is allowed.
C. **Shunting Data Enrichment:** It takes the produced (Step A.) and adapted (Step B.) shunting data tables to enrich the schedule according to the given shunting definitions.
D. **Demand Data Conversion:** Based on Step C. (or A. - if no adaption is done) this process creates the wagon demand which need to be routed. It needs again well-defined but specialized input data formats defining the demand. The process produces MATSim demand.
E. **Route Optimization:** This is the MATSim optimization cycle (Controller). Most of the MATSim configuration is predefined for the wagon routing process, so no config.xml file is needed. It runs the optimization for 50 iterations. Apart from the well-known MATSim output data, two additional data files are produced per iteration, one for stuck agents (wagons that cannot be delivered to their destination) and one for the load of the locomotives per departure and stop.

The MATSim output can then be analyzed in the normal way by using VIA or writing your own analysis source code.

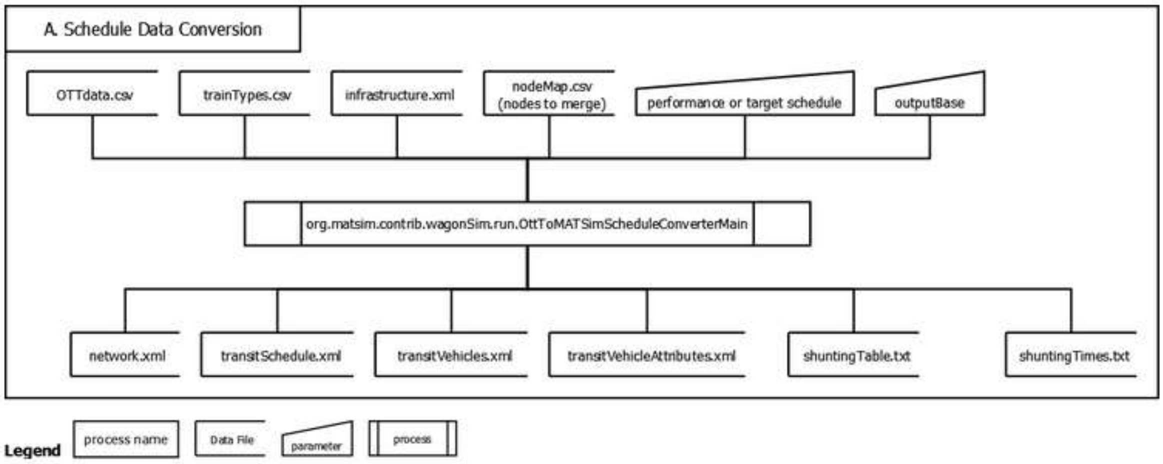
The full process chain with detailed input and output data sets is shown in Appendix A.

Process Step A: Schedule Data Conversion

Functionality

The OttToMATSimScheduleConverterMain process converts well defined but specialized input data into MATSim network, schedule, vehicles and vehicleAttributes together with defaults for minimum shunting times and shunting allowance.

Calling the Process



The process will be called via command line, resp. as a Windows batch file (*.bat), resp. as a Shell script for Linux or Mac (*.sh). The one line command structure (for Windows) is:

```
java -Xmx1024m -cp matsim-0.6.0-SNAPSHOT.jar;wagonSim-0.6.0-SNAPSHOT.jar ^
    org.matsim.contrib.wagonSim.run.OttToMATSimScheduleConverterMain ^
    ../input/20130715_Fahrplandaten/OTT_20120308.csv ^
    ../input/20130715_Fahrplandaten/Traintypes.csv ^
    ../input/20130524_Daten_Infrastruktur/._infra.xml ^
    ../input/20130828_nodeMergeList/NodeMap.csv ^
    true ^
    ../output/schedulePerformance > OttToMATSimScheduleConverterMain.log 2>&1
```

For Linux or Mac replace the ; with a : and the ^ with a \)

The Elements are described below. Parts denoted with brackets ([]) can be adapted.

`java`	Calling Java virtual machine. Has to be installed on the computer. (To test, call "`java -version`")
`-Xmx[MBYTES]m`	Maximum memory assigned for the process. Replace [`MBYTES`] with a number
`-cp matsim-0. ...` `OttToMATSimScheduleConverterMain`	main process call
`[OTT data file location]`	the location of the OTT data file. See Appendix B for the data file format.
`[train types file location]`	the location of the train types file. See Appendix C for the data file format.
`[infrastructure data file location]`	the location of the network data ("infrastructure") file. See Appendix D for the data file format.
`[node map file location]`	the location of the node map data file. See Appendix E for the data file format.
`[true/false]`	User attribute: defines if the performance data (`true`) or the target data (`false`) of the OTT file will be converted into a schedule. See Appendix B for details.
`[output folder location]`	defines where to write the output data files. The folder has to be Empty or not existing.
`> OttToMATSimScheduleConverterMain.log 2>&1`	writing all logging information of the process into the logfile

Resulting MATSim Scenario Data

The resulting data sets describes already the complete supply side of a MATSim scenario. It contains:

- The **network.xml** (rails as links and train stations as nodes) as a pseudo rail network. It interconnects all stations by links as defined by the transit schedule (the sequences how train stations are served by the trains). The train station coordinate is extracted by the infrastructure data file (see Appendix D for details).
- The **transitSchedule.xml** defines each transit stop facility served by locomotives and their schedule. In this process step, **every** transit stop of a locomotive trip is served meaning that at each stop wagons can enter or leave a train.
- The **transitVehicle.xml** defines for each trip of the schedule a separate locomotive. Note, that as the preparation of the MATSim optimization process, the schedule starts at the second day (departure time plus 24 hours). This is necessary since some trips starts already before midnight. So, the shift of 24 hours is necessary. Furthermore, the schedule is copied twice to the following two days to take care that left over wagons will be transported the days later. It ends up that every locomotive trip of the OTT data file is produced three times, the first at time + 24 hours, the second at time + 48 hours and the third at time + 72 hours.
- The **transitVehicleAttributes.xml** contains the capacity constraints for train length and train weights as well as the speed for each locomotive at each link. See Appendix F for the attribute description.
- The **shuntingTimes.txt** table defines the minimum shunting time per transit stop facility. For all stops the default minimum shunting time of 900 seconds is set. The table can be used for (manual) adaption (see Process Step B.). The data format is described in Appendix G.
- The **shuntingTable.txt** holds for each locomotive-trainStop-pair a flag if shunting is allowed. For all pairs the default flag is set to true, which means that shunting is allowed for all locomotives at all stations. The table can be used for (manual) adaption (see Process Step B.). The data format is described in Appendix H.

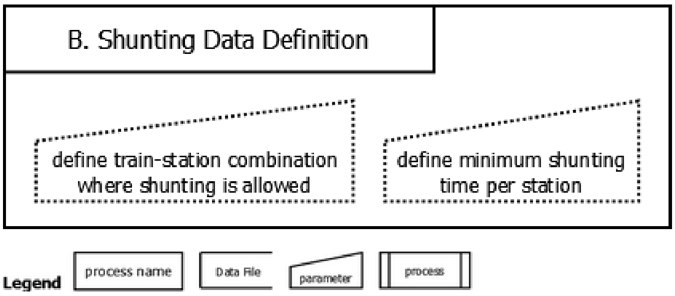
As a summary, the output of Process Step A. delivers already everything you need except the wagon demand (see Process Step D.). The steps in between are used to enrich the scenario with customized shunting times and allowance. (See following sections)

Process Step B: **Shunting Data Definition**

Functionality

This is actually a manual (handmade or your own process) adaption of the shuntingTimes.txt and shuntingTable.txt file. The file format description can be found in Appendix G and H. The data will be used in the next Process Steps to enrich the scenario with the adaptations you've done in the two data files.

Calling the Process



Simply open the file with a text editor. You can also import it into e.g. Excel, edit it there and export it again into the text format. BTW: The easiest way to import/export the data from/to Excel is actually copy/paste.

Results

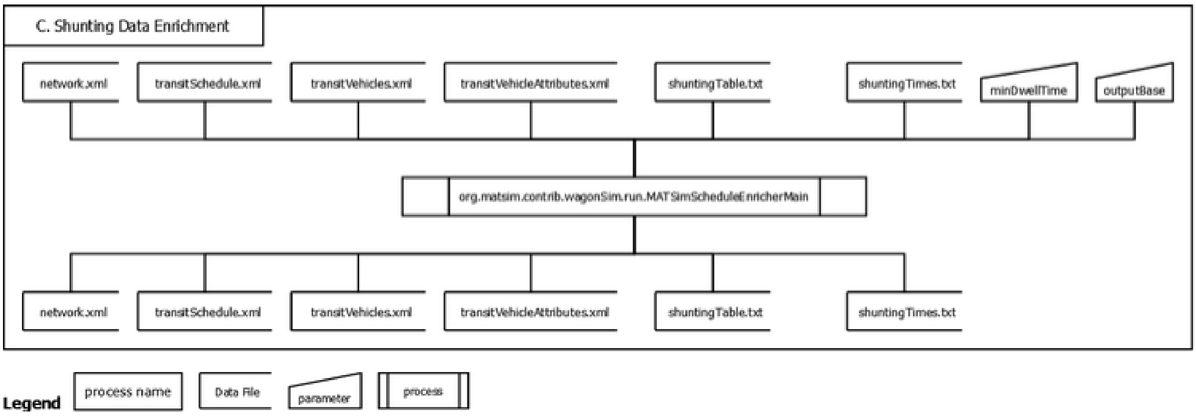
The resulting files are again the shuntingTimes.txt and shuntingTable.txt files with correct data format as described in Appendix G and H. The files are used by Process Step C.

Process Step C: **Shunting Data Enrichment**

Functionality

The process uses the output of Process Step A and the manually changed shunting data from Process Step B to adapt the MATSim scenario to the user defined shunting data. More precisely it removes transit stops of transit routes from the **transit schedule** where shunting is not allowed and replaces that with a link on which the train spends as many seconds as given by the shedule. The **shuntingTable.txt** together with the **minDwellTime** parameter defines if shunting is allowed for a specific train at a specific stop.

Calling the Process



The process will be called via command line, resp. as a Windows batch file (*.bat), resp. as a Shell script for Linux or Mac (*.sh). The one line command structure (for Windows) is:

```
java -Xmx1024m -cp matsim-0.6.0-SNAPSHOT.jar;wagonSim-0.6.0-SNAPSHOT.jar ^
    org.matsim.contrib.wagonSim.run.MATSimScheduleEnricherMain ^
    ../output/schedulePerformance/network.ott.performance.xml.gz ^
    ../output/schedulePerformance/transitSchedule.ott.performance.xml.gz ^
    ../output/schedulePerformance/transitVehicles.ott.performance.xml.gz ^
    ../output/schedulePerformance/transitVehicleAttributes.ott.performance.xml.gz ^
    ../output/schedulePerformance/shuntingTable.ott.performance.txt ^
    ../output/schedulePerformance/shuntingTimes.ott.performance.txt ^
    600 ^
    ../output/schedulePerformanceEnriched > MATSimScheduleEnricherMain.log 2>&1
```

For Linux or Mac replace the ; with a : and the ^ with a \)

The Elements are described below. Parts denoted with brackets ([]) can be adapted.

`java`	Calling Java virtual machine. Has to be installed on the computer. (To test, call "`java -version`")
`-Xmx[MBYTES]m`	Maximum memory assigned for the process. Replace [`MBYTES`] with a number
`-cp matsim-0. ...` `MATSimScheduleEnricherMain`	main process call
`[network file location]`	the location of the MATSim network file. (E.g. created by Process Step A).
`[transitSchedule file location]`	the location of the MATSim transit schedule file. (E.g. created by Process Step A).
`[transitVehicle file location]`	the location of the MATSim transit vehicle file. (E.g. created by Process Step A).

`[transitVehicleAttributes file location]`	the location of the MATSim object attributes file containing parameters for each locomotive of the scenario. (E.g. created by Process Step A). See Appendix F for the attribute description.
`[shunting table file location]`	the location of the table defining for each locomotive-stop-pair if shunting is allowed. (E.g. created by Process Step A and manually adapted by Process Step B). See Appendix H for details.
`[shunting times file location]`	the location of the table defining for each stop the minimum time to do shuning of a wagon.(E.g. created by Process Step A and manually adapted by Process Step B). See Appendix G for details.
`[minimum dwell time parameter]`	This parameter (given as **Integer** with unit **seconds**) defines according to the dwell time of each locomotive at each station given by the input MATSim **transitSchedule** file if shuning is possible. **NOTE**: It only plays a role for locomotive-stop-pairs that are **NOT** defined in the **shunnting table** file. If all pairs of the scenario are defined, this parameter has no affect. On the other hand, If the shuning table does not contain **ANY** pair (only the table header) then the process will use this parameter for all locomotive-stop-pairs to deside, if shunting is allowed. Therefore, the combination of the shuning table and this parameter allows one to flexibly define if shuning is allowed/not allowed for specific locomotive-stop-pairs and set the remaining ones according to the default given by this parameter.
`[output folder location]`	defines where to write the output data files. The folder has to be Empty or not existing.
> MATSimScheduleEnricherMain.log 2>&1	writing all logging information of the process into the logfile

Resulting MATSim Scenario Data

The resulting data sets define again the complete supply side of a MATSim scenario similar to Process Step A. The difference are based on the manual adapted shuning data files to respect special shunting times and dwell times. The data sets contain:

- The **network.xml** (rails as links and train stations as nodes) with almost the same topology as the input MATSim network. The difference are only that additional "dwell links" are created as a loop at a train station whenever a train need to spend time at that station without allowence to shunt. These "dwell links" are created as follow:
  - `linkId := transitStopFacilityId` (the train stop Id)
  - `length := 50 [m]`
  - `freespeed := 99999` (not used for the simulation. therefore very high)
  - `numberOfLanes := 1`
  - `allowedModes := pt`
- The **transitSchedule.xml** with almost the same structure as the input schedule file. he difference are that stops of the transit route stop list that do not allow shunting are removed and replaced by the "dwell link" added in the network (see above).
- The **transitVehicle.xml** is the same as the input transit vehicle file.
- The **transitVehicleAttributes.xml** contains the smae information as the input attributes but enriched by additional link travle speeds for the created "dwell links". See Appendix F for the attribute description.
- The **shuntingTimes.txt** stays the same as the input shunting times except that missing train stations are set to a default minimum schuning time. The data format is described in Appendix G.
- The **shuntingTable.txt** holds for all locomotive-trainStop-pair a flag if shunting is allowed byed on the input shuning table and the minDwellTime paramter. **NOTE** that for the first and the last stop of a locomotive shuning is **ALWAYS** allowed. The data format is described in Appendix H.

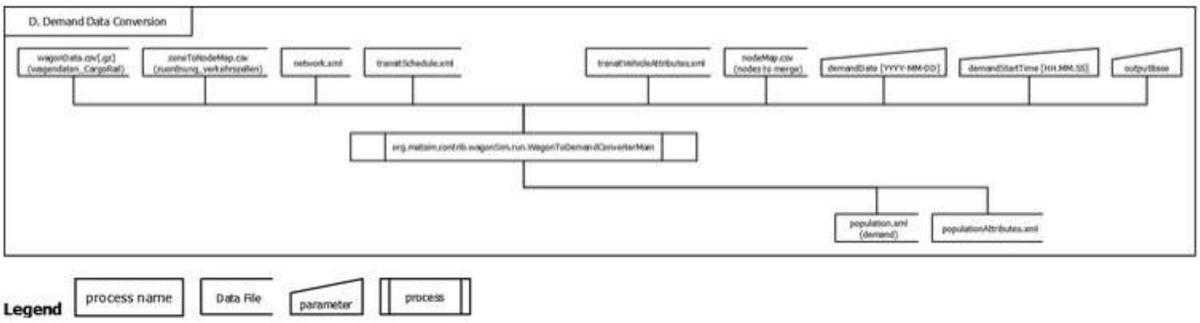
The ouput of this process delivers the complete and user defined supply side which will be part of the input of the Route Optimization Process.

Process Step D: Demand Data Conversion

Functionality

Given the complete supply side of the scenario (e.g. produced by Process Step A or C) and a well defined but specialized input demand data set, the process creates MATSim demand for the route optimization process. More precicly it creates an agent out of each given wagon with exactly two activities and one trip (single trip agents). The start activity is of type "`origin`" with coordinate equals to the start train station while the end activity is of type "`destination`" and placed at the destintation train station. Activity end time (same as trip start time) is given as a user defined input parameter.

Calling the Process



The process will be called via command line, resp. as a Windows batch file (*.bat), resp. as a Shell script for Linux or Mac (*.sh). The one line command structure (for Windows) is:

```
java -Xmx1024m -cp matsim-0.6.0-SNAPSHOT.jar;wagonSim-0.6.0-SNAPSHOT.jar ^
    org.matsim.contrib.wagonSim.run.WagonToDemandConverterMain ^
    ../input/wagendaten_2012_CargoRail.csv.gz ^
    ../input/zuordnung_verkehrszellen_CargoRail_2012.csv ^
    ../output/schedulePerformanceEnriched/network.enriched.xml.gz ^
    ../output/schedulePerformanceEnriched/transitSchedule.enriched.xml.gz ^
    ../output/schedulePerformanceEnriched/transitVehicleAttributes.enriched.xml.gz ^
    ../input/NodeMap.csv ^
    2012-06-14 ^
    14.00.00 ^
    ../output/schedulePerformanceEnrichedDemand > WagonToDemandConverterMain.log 2>&1
```

For Linux or Mac replace the ; with a : and the ^ with a \)

The Elements are described below. Parts denoted with brackets ([]) can be adapted.

`java`	Calling Java virtual machine. Has to be installed on the computer. (To test, call "`java -version`")
`-Xmx[MBYTES]m`	Maximum memory assigned for the process. Replace [MBYTES] with a number
`-cp matsim-0. ... WagonToDemandConverterMain`	main process call
`[wagon data file location]`	the location of the wagon data file. See Appendix I for the data file format.
`[zone to station map file location]`	the location of the file containing zone id to train station id map. See Appendix J for the data file format.
`[network file location]`	the location of the MATSim network file. (E.g. created by Process Step A or C)
`[transit schedule file location]`	the location of the MATSim transit schedule file. (E.g. created by Process Step A or C)
`[transit vehicle attributes file location]`	the location of the MATSim object attributes file containing parameters for each locomotive of the scenario. (E.g. created by Process Step A or C) See Appendix F for the attribute description.
`[node map file location]`	the location of the node map data file. See Appendix E for the data file format.

`[demandDate]`	Parameter to specify which date to extract from the wagon data file. Date format: `[YYYY-MM-DD]`
`[demandStartTime]`	Parameter to define which time the trips of ALL wagons start will be part of the MATSim demand (actvitiy end time). Time format: `[HH.MM.SS]`
`[output folder location]`	efines where to write the output data files. The folder has to be Empty or not existing.
`> WagonToDemandConverterMain.log 2>&1`	writing all logging information of the process into the logfile

Resulting MATSim Scenario Data

The resulting data sets describes the complete demand of the MATSim scenario based on the given supply side (create by e.g. Process Step A or C). It contains:

- The **demand.wagons.xml** describes the the agent demand representing each single wagon of the scenario with exactly one trip departing at the given `demandStartTime`.
- The **wagonAttributes.xml** contains for each wagon its gross weight and its length. See Appendix K for details.

The process therefore procides a suitable format for the given, well defined but specialized input data for the wagon demand.

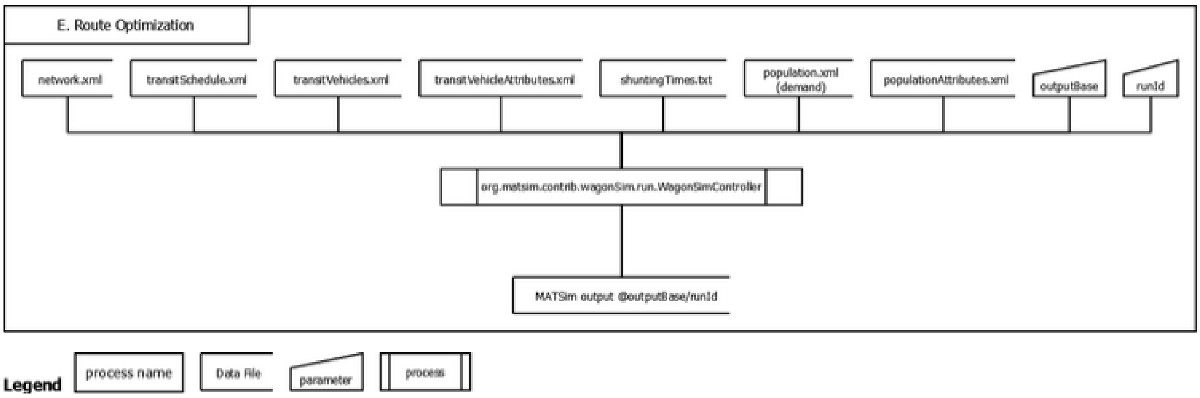
Process Step E: Route Optimization

Functionality

Finally, the MATSim scenario is prepared (supply side from Process Step A, B and C; demand side from Process Step D) to run MATSim's route optimization process. Since the agents are here the wagons with their single trip demand from a given and fixed origin and destination and since trip departure time (actvitiy end time) is given and fixed as well (see Process Step D) the optmization process calculates the optmial routes for each wagon through the infrastructure (network, schedule, locomotives with their length and weight constraints, shunting stations and the minimum shunting times) in competition with the demand of all other wagons.

In constrast to the usage of a standard MATSim demand optimization process no run configuration file (config.xml) has to be given since most of the configration parameters are fixed for this process. In simply requires the location of the input data as generated by the previous processes.

Calling the Process



The process will be called via command line, resp. as a Windows batch file (*.bat), resp. as a Shell script for Linux or Mac (*.sh). The one line command structure (for Windows) is:

```
call ^
java -Xmx1024m -cp matsim-0.6.0-SNAPSHOT.jar;wagonSim-0.6.0-SNAPSHOT.jar ^
    org.matsim.contrib.wagonSim.run.WagonSimController ^
    ../output/schedulePerformanceEnriched/network.enriched.xml.gz ^
    ../output/schedulePerformanceEnriched/transitSchedule.enriched.xml.gz ^
    ../output/schedulePerformanceEnriched/shuntingTimes.enriched.txt ^
    ../output/schedulePerformanceEnriched/transitVehicles.enriched.xml.gz ^
    ../output/schedulePerformanceEnriched/transitVehicleAttributes.enriched.xml.gz ^
    ../output/schedulePerformanceEnrichedDemand/demand.wagons.xml.gz ^
    ../output/schedulePerformanceEnrichedDemand/wagonAttributes.xml.gz ^
    ../output/ ^
    run0001 > WagonSimController.log 2>&1
```

For Linux or Mac replace the ; with a : and the ^ with a \)

The Elements are described below. Parts denoted with brackets ([]) can be adapted.

`java`	Calling Java virtual machine. Has to be installed on the computer. (To test, call "`java -version`")
`-Xmx[MBYTES]m`	Maximum memory assigned for the process. Replace [MBYTES] with a number
`-cp matsim-0. ... WagonSimController`	main process call
`[network file location]`	the location of the MATSim network file. (E.g. created by Process Step C).
`[transitSchedule file location]`	the location of the MATSim transit schedule file. (E.g. created by Process Step C).
`[shunting times file location]`	the location of the table defining for each stop the minimum time to do shuning of a wagon.(E.g. created by Process Step C). See Appendix G for details.
`[transitVehicle file location]`	the location of the MATSim transit vehicle file. (E.g. created by Process Step C).
`[transitVehicleAttributes file location]`	the location of the MATSim object attributes file containing parameters for each locomotive of the scenario. (E.g. created by Process Step C). See Appendix F for the attribute description.
`[wagon demand file location]`	the location of the MATSim demand (wagons as single trip agents) file (created by Process Step D).

[wagon attributes file location]	the location of the object attributes file containing parameters (gross weight and length) for each wagon of the scenario (created by Process Step D). See Appendix K for details.
[output folder location]	Defines where to write the MATSim output run folder and its data. That folder has to exist.
[run name]	Defines the name of the run. It's used to (i) create a the run folder inside the [output folder location] (that run folder must not exist) and (ii) it uses that name as prefix for the various MATSim output files.
> WagonSimController.log 2>&1	writing all logging information of the process into the logfile

MATSim's Route Optimized Demand And Simulation Data

MATSim calculates and optimizes the wagon routes and create a final relaxed demand (wagon routes) as well as it's simulation during the defined simulation period. As usual it creates for each iteration the indermedian demand and simulation data and stores it at an iteration directory @[ouput folder location]/[run name]. For wagonSim 50 iterations are done which is sufficient to relax the demand.

Apart form the typical output data sets MATSim produces and additional file is created in each directory listing the agent ids (wagon) that could not be transported to their final destination (stuck agents). These files are called `[run name].[iteration number].stuckAgents.txt`. In a well balanced scenario between demand and supply only a few or no agents should be stuck.

Most of the output data files are MATSim standards but are not really useful for the wagonSim package. The datafiles that are actually needed for analysis (by using VIA or with your own analysis source code) and for further desision making processes are:

- **[output folder location]/[run name]/[run name].output_network.xml.gz**: The MATSim network (the same as the input MATSim network).
- **[output folder location]/[run name]/[run name].output_transitSchedule.xml.gz**: The MATSim schedule (the same as the input MATSim schedule).
- **[output folder location]/[run name]/[run name].output_vehicles.xml.gz**: The MATSim transit vehicles (the same as the input MATSim transit vehicles).
- **[output folder location]/[run name]/ITERS/it.50/[run name].50.plans.xml.gz**: The MATSim demand (the wagon demand - as given in the input - while containing the optimized routes for each wagon demand).
- **[output folder location]/[run name]/ITERS/it.50/[run name].50.events.xml.gz**: The MATSim simulation data (to visualize and analyse the movements of each wagon as well as each locomotive during the complete simulation period).
- **[output folder location]/[run name]/ITERS/it.50/[run name].50.stuckAgents.txt**:The list of agent ids (wagon ids that could not be transported to the final destination).

Use that dataset for your further analysis.

Appendix

Appendix A: Complete Wagon Sim Process Chain