IMPROVING RAIL FREIGHT MODELLING IN SWEDEN

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ABSTRACT

Transport models are used as decision-support tool by a wide range of actors. One important field is infrastructure investments and policy where decisions are often both long-term and connected with high capital expenditures. At the same time current national freight transport models show shortcomings. It is especially difficult to use the models on geographically disaggregated level. Problems are first and foremost related to the modelling of rail freight, due to the specific characteristics and complexity of it's production system.

The Swedish Road Transport Research Institute (VTI) together with the Railway Group of the Royal Institute of Technology Stockholm (KTH) have therefore started a project with the aim to improve the modelling of rail freight (benefitting even the modelling of intermodal transport, where rail is involved). The three-year project RAILTRAM (Improvement of Rail Transport Modelling) is carried out at the Centre for Transportation Studies (CTS) Stockholm.

The overall research question behind the project is: How can the modelling of rail freight be improved by combining the Swedish national logistics model LOGMOD and the disaggregated rail freight cost model EVARAIL? LOGMOD is based on an aggregate-disaggregate-aggregate approach, it is a module within the new national Swedish national transport model system and covers all modes of transport.

The paper breaks down this overall research question into a number of sub-questions and presents an outline for a modelling approach, addressing specific areas of improvement. The solutions presented may be useful for improvement of other freight transport models as well.

Keywords: transport model, logistics model, rail freight, intermodal, transport policy decision support-tool

INTRODUCTION

STRUCTURE OF THE PAPER

The paper starts with a short description of the background of the project, underlining the relevance of the project for different stakeholders, leading to the next two sub-chapters containing the justification and scope of the project.

The next main chapter is the problem analysis, identifying shortcomings of the Swedish national transport model system when it comes to the modelling of rail freight. Based on this analysis the overall research question - how can the modelling of rail freight be improved by combining the Swedish Logistics Model LOGMOD with the disaggregated rail freight cost model EVARAIL – is broken down into a number of sub-questions.

That chapter is followed by a chapter presenting an outline of a modelling approach, first describing the main features of the LOGMOD and EVARAIL models, and thereafter presenting integrated solutions, which combine both models. Even some possibilities for long-term further development are shortly discussed.

The paper ends with conclusions, giving answers to the research questions.

BACKGROUND

Transport models are an important instrument to support decision-making when it comes to design and use of transport systems. In freight transport – to which this paper confines itself – there is a wide range of stakeholders both in the public as well as the private sector which are users of the results from transport models (see table I). These actors use this information for different purposes, but it is important to note that often their decisions not only affect themselves, but even other actors and parties within the sector as well as outside the transport sector.

Policy and infrastructure decisions are one central area in which transport models are frequently used, making their existence, deployment and further development a public interest. One policy-area which worldwide is receiving increasing attention and in whose context the transport sector – and thus transport models – have come into special focus, is the need to counteract Climate Change. Policy measures under consideration to achieve this comprise efficiency improvements within the various transport modes, development of intermodal transport as well as actions aiming at modal shift. Especially the competitive situation between road and rail is repeatedly coming into focus, since measures affecting it are a hot topic in the public discussion and in political decision-making.

Table I – Fields in which different actors/parties may use the output from transport models

Transport service providers / railway undertakings	Shippers	Government and public administration Infrastructure Managers	Society	Researchers
Design of services Investments in rolling stock Operations planning Business strategies	Choice of transport solution / transport mode Logistical planning	Regulation and legislation Infrastructure investments and maintenance Taxation / Subsidies	Opinion-forming related to policy-measures Participation in political and administrative decision-processes	Model development (demand forecast) Evaluation of transport systems

Transport models are used to assess policy measures (or bundles of measures) such as the impacts of infrastructure charges and investments or changes in the technical parameters of the transport system, e.g. when in comes to rail freight changes in train-lengths, axle-loads, etc. They are also used to assess impacts of external factors such as the development of the energy prices. The wide range of actors and parties participating in, or affected by these decisions make that transport models are expected to quantify the impacts on different levels, e.g. on the transport system as a whole as well as on various transport modes and on single transports or goods flows.

Justification of the project

In order to be able to serve as a decision-support tool, relevance and quality of results from transport models are crucial. To date national freight transport models are only partly able to model competition and co-operation between transport modes in an adequate way. A thorough understanding of the interaction and competitive situation between the transport modes is necessary, and this must also be reflected in the models in order to assess effects of policy-measures correctly.

An important reason for the difficulties to model the competitive situation of rail freight are shortcomings in the modelling of rail freight itself, whose production system is characterized by high variety and complexity. This also affects the modelling of intermodal transport, where rail often forms the main transport mode.

The lack of reliability of results when rail freight is involved is especially noticeable when it comes to specific links, nodes, regions or transport flows. This constitutes a problem insofar as infrastructure investments always are local or regional, i.e. related to specific links or nodes in the network. This means that transport models have to be able to deliver results, which also can be used on the local/regional level. In this context one has to be aware of, that on quite many railway lines relatively few large goods flows constitute a high portion of the total traffic on those lines (in comparison to the road sector where cargo from a large number of small shippers is transported), making the modelling of rail freight even more challenging.

The Swedish National Freight Transport model system SAMGODS has been considerably improved compared to the former aggregated model (that was based on the STAN-software) by inclusion of a logistics model LOGMOD. The logistics model is based on an aggregate-disaggregate-aggregate approach (ADA-approach) which means that aggregated zone-to-zone flows between sender and receiver (PC Production consumption) are disaggregated to firms where logistic decisions are taken and than aggregated to OD-vehicle flows (OD = origin- destination) that are assigned to the network. But there are still shortcomings when it comes to rail freight (including intermodal transport involving rail).

Therefore a project has been started that combines the Swedish National logistics model LOGMOD with the disaggregated rail freight cost model EVARAIL, which has been developed at the Royal Institute of Technology (KTH) Stockholm. The conceptual starting point is to create an interface between the logistics model (that covers all modes) and the rail transport cost model. The paper presents an approach to go further in the aggregate-disaggregate-aggregate method and combine an aggregate freight model with a disaggregate rail transport costs model. The three-year project with the name RAILTRAM – Improvement of *Rail Tra*nsport *M*odelling – is carried out at the Centre for Transportation Studies Stockholm (CTS) in cooperation between the Swedish Road Transport Research Institute (VTI) and the Railway Group of the Royal Institute of Technology.

Scope

Geographically the model system covers freight transports in, to, from and through Sweden by all modes. This means that transport networks are modelled, though with decreasing level of detail the bigger the distance is from Sweden. Within rail freight all production subsystems – Trainload, Wagonload and Intermodal Transport are covered, though special attention is given to Wagonload and Combined Transport, which stand out with their high complexity. Concerning intermodal transport the combinations rail/road and rail/sea are covered.

The project focuses on medium- to long-term policy decisions with a time horizon of typically about at least one year (e.g. setting of infrastructure charges, changes of transport service concepts) up to several years/decades (e.g. infrastructure investments, changes in technical parameters of the rail freight system).

The project certainly deals with the improvement of the Swedish National Transport model system, however, similar weaknesses in the modelling of rail freight can be found in other transport models as well, for example even in the European transport model TRANS-TOOLS[1], which may make solutions presented in this paper relevant and applicable in connection with other models as well.

[1] Compare: ftp://ftp.jrc.es/users/transtools/public/Documentation/TTv2_Training/Transtools%2520Capabilities_v2.pdf, p.25

PROBLEM ANALYSIS RELATED TO MODELLING

Shortcomings concerning rail freight in current models

The reasons why just the modelling of rail freight is so demanding and more difficult than other transport modes are several:

1. Rail freight operators use different production systems; many of these are characterized by a high level of complexity compared to those for road and maritime transport. One important reason for this complexity is that the train building function adds one more consolidation level; a characteristic of the rail freight system, which allows a level of consolidation unknown to other transport modes. Rail freight is also more difficult to model than rail passenger transport, where the market is more conform and demand relatively stable. This means that neither the modelling approach for other modes nor that for rail passenger transport is very suitable for rail freight. A train may convey not only wagons belonging to different PC- or OD-flows, but also different commodities Consolidation both geographically and across commodities constitutes also a challenge when it comes to transport cost calculation. To this complexity also adds that production systems for rail freight can be combined with each (e.g. combination of intermodal and wagonload services).

2. One can also note a trend towards increased intermodality, i.e. transport systems are becoming more integrated in the sense of technical, physical and logistical combination of different modes. Both land intermodal transport as well as hinterland traffic from and to ports is developing fast. The growing popularity of intermodal transport solutions makes use of a variety of different intermodal techniques (e.g. containers, swap-bodies, semitrailers), with different technical and operational characteristics and different cost structures, which creates further challenges for modelling.

3. The rail sector in Sweden and Europe has undergone structural changes during the past 15 years, resulting in the emergence of intramodal competition. New railway operators have entered the market adopting different business models and also introducing new production methods. In prolongation this had an impact on the supply and production side of rail freight as well as on the quality and pricing of rail freight services. One effect is that intramodal competition has reduced the possibilities to cross-subsidize different rail transports and that pricing has become more based on the costs for individual services. From a modelling point of view this has both advantages and disadvantages: As an advantage can be seen that it is easier to derive transport prices from costs (an overall assumption is that prices corresponds to

costs incl profits; a disadvantage however is that transport costs need to be calculated on a more detailed level and cannot simply rely on an average system cost approach. The sometimes fast organizational changes in the railway sector are often not reflected by current national transport models, partly due to the long lead-time in the development of models, making that they often rather reflect a reality in the past.

4. Different physical characteristics of different commodities with regard to value, weight density, stowage factor and logistic requirements are complicating commodity-specific transport cost calculations. This problem is not limited to rail transport, however, since, as mentioned above, rail serves large flows and normally long distances the problem it is more accentuated.

There is generally little information publicly available especially about the economic side of rail freight. Costs and cost-structures are not well-known except within a small circle of experts and often kept in-house by the market actors. The rail freight market is dominated by relatively few players both on the supply and demand side, which partly explains why much of the information is considered being sensitive. To this adds that the railway sector traditionally has been more “closed” than the road or maritime transport sector.

When it comes to modelling, this situation can at least partly be handled by choosing a bottom-up approach in the calculation of transport costs. The transport cost calculation in EVARAIL is based on such a bottom-up approach, using costs for different resources (e.g. locomotives, wagons, personnel, energy, etc.) and activities (e.g. shunting) as input-data and calculating transport costs on flow-level. Resource utilization is to a wide extent is calculated within the model. This approach relies on a detailed modelling of the rail freight system, up-to-date expert knowledge about costs for different resources and in-depth knowledge about the services run by different rail freight operators in Sweden. This knowledge has been obtained from studying rail-based transport solutions and from experts working within the railway sector.

Research questions

Based on the problem analysis concerning modelling the overall research question can be broken down into the following sub-questions:

- How to calculate transport costs in rail freight and intermodal transport chains?
- How to model consolidation in the rail freight system?
- How to take into account different intermodal transport techniques
- How to reflect different transport cost structures for different commodities?
- How to handle the influence of institutional changes on rail freight production and pricing of services?

OUTLINE OF A MODELLING APPROACH

The conceptual approach to address the shortcomings identified in the previous chapter is to combine two different models, LOGMOD and EVARAIL. In the first part of this chapter both models are shortly described, followed by a presentation of the outline for integrated solutions where both models cooperate.

LOGMOD

In Sweden an aggregate-disaggregate-aggregate (ADA) approach, (see figure 1), for logistic decisions has been developed as part of the new national transport model system, it includes all modes. The logistics model is called LOGMOD[2] and is developed in cooperation between Swedish and Norwegian agencies. The algorithms in LOGMOD are developed by Gerard de Jong and Ben-Akiva and are described in DE JONG, G.,et.al. (2008).

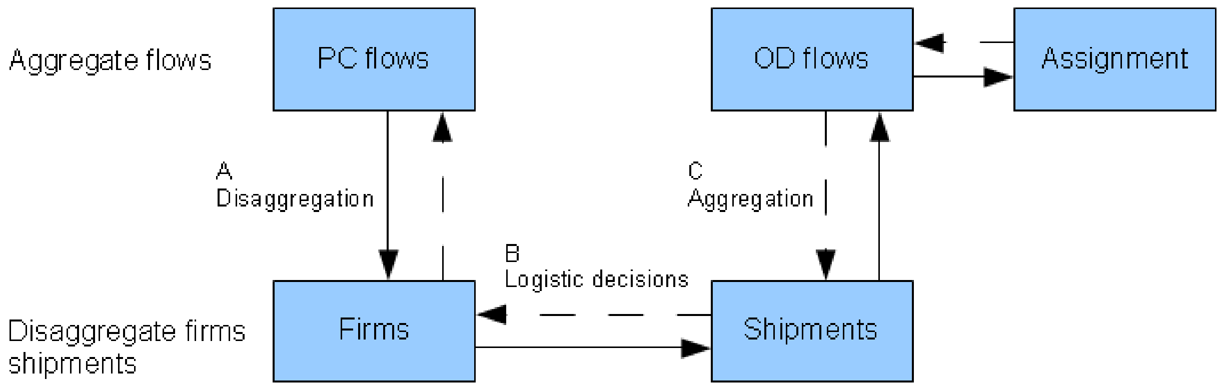

Figure 1 – ADA structure of the (inter)national/regional freight transport model system

LOGMOD takes as input annual transport demand between production and consumption (PC flows) and produces OD flows (tonnes and vehicles) for network assignment. The LOGMOD consists of three steps:

A. Disaggregation to allocate zone to zone flows to individual firms[3] at the P (production) and C (consumption) end;
B. Models for the logistics decisions by the firms (e.g. shipment size, use of consolidation and distribution centres, modes, loading units such as containers and empty transports);

[2] Within the RAILTRAM-project it is planned to use the beta version of LOGMODl made available by SIKA 30-03-2010 with the separate parts named as follows: L220310, B250908, S121109.
[3] A firm is assumed to be located at one geographically specified location in LOGMOD. At this location decisions are made. Thus, LOGMOD doesn't handle global decisions e.g. from a worldwide company´s headquarter.

C. Aggregation of the information per shipment to origin-destination (OD) flows of vehicles for network assignment.

LOGMOD is a deterministic model that defines shipment sizes and transport chains at company/firm level based on minimization of the annual logistics costs. It includes a consolidation function within each commodity group. LOGMOD reflects logistic decisions at the firm level. In- and outputs are stored in text formatted files and the structure for the user is illustrated in the figure below.

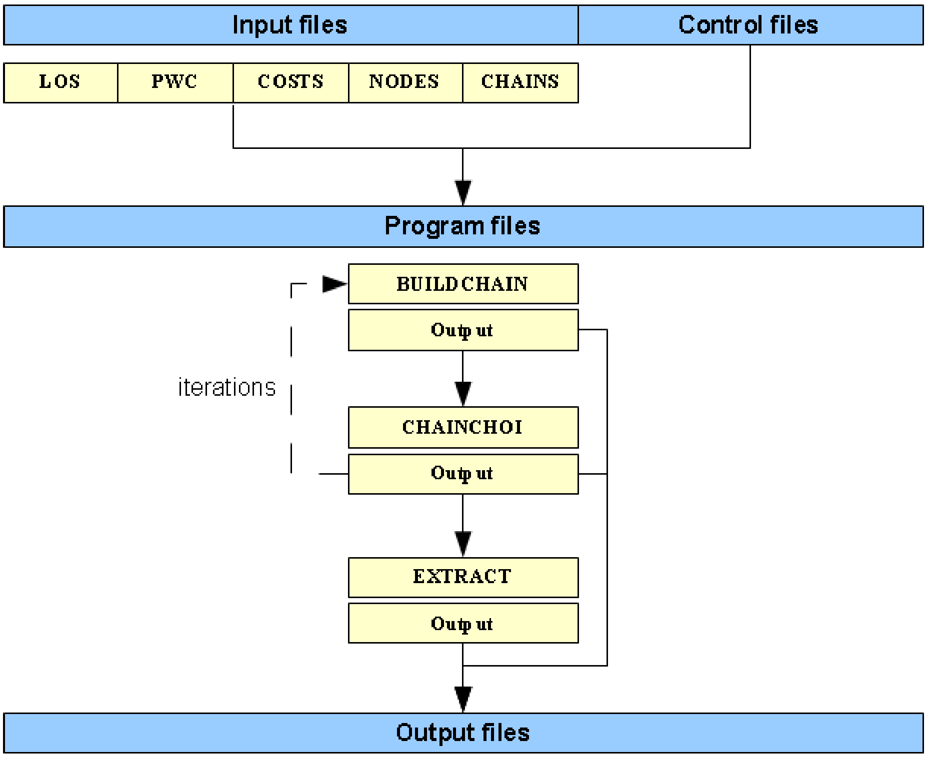

Figure 2 – LOGMOD-model structure

As input LOGMOD takes: (1) LOS matrices (LOS = level of service) describing the characteristics of the links in the network inside and outside Sweden (i.e. trains max gross weight) and the service frequencies (i.e. five trains per week); (2) PC matrices or also called PWC matrices there the W stands for wholesale. The model comprises commodity-specific production-consumption matrices (PC-matrices representing senders and receivers); (3) The COSTS-files comprise characteristics and costs for different commodites and vehicle types; (4) In the NODES-files the characteristics of access points and nodes are specified e.g. marshalling yards.; (5) All allowable transport chains are specified in the CHAINS file. Example of chains; road–sea-rail, rail-sea, sea -rail-road etc. (6) CONTROL-files: the programs Build chain, Chain choice and Extract use different control files that tell the program how to calculate and what outputs to give. The control files also contain some start values and information on how to handle the input files.

LOGMOD discerns different vehicle types per mode, of which seven are trains (three train load trains, three wagon load trains and one container[4] load train). It is relatively easy to implement new train types but this is limited to whole trains not separate wagons. Thus, the model does not handle train building (and limitations of available wagons). The costs are thereof given for whole train sets and it is not possible to combine different wagon types in a train. Another characteristic is that LOGMOD does not handle time tables instead it uses departure frequencies given per week. (Time tables can be difficult to handle when forecasts are done for several years ahead.)

The main output of the logistics model are OD-matrices per vehicle type (train type when is comes to rail). The handling of empty transports is handled in the same simple way as for road transports. The difference between vehicles for one OD-pair is filled up with empties in that direction that has less vehicles. Applying this assumption means that all trains arriving at a destination will go back to the origin it came from.

Annual commodity specific logistic costs (including break down to components) and costs and time per shipment are calculated (including break down to components). The model delivers also information on load factor per vehicle type and OD-pair and tonkm performed inside and outside Sweden. The merge program aggregates over all commodities.

LOGMOD is a computer based model programmed in language Delphi. LOGMOD is as mentioned above a part of the national freight transport model system SAMGODS and SAMGODS uses CUBE[5] for geographical and graphically presentations.

EVARAIL

EVARAIL is a rail transport cost model developed by Gerhard Troche at the Royal Institute of Technology. It stands for *Model for Economic evaluation of rail freight services*. EVARAIL is limited to rail freight and calculates transport costs on both system level for rail, i.e. a whole rail transport service network, and flow level.

The goal was to develop a model, which makes it possible to calculate transport costs on different levels of aggregation (e.g. on transport/flow level, production system level, overall rail freight system level), enhance the understanding of costs in rail freight and to analyse possible ways to improve the profitability or cost competitiveness of the rail freight system and how these improvements affect different flows.

Costs can be calculated for transports in different rail freight production systems, including combinations of them. Production systems in rail freight can be understood as service concepts directed to transport customers as well as the sum and specific arrangement of all production resources – material as immaterial – necessary to carry out a certain transport task. The ambiguous usage of the term can be ascribed to the fact that the resources often

[4] With container we in this case mean different load units. Load units can be trailers, containers, swap-bodies and alike.
[5] http://www.citilabs.com/cube_base.html

to some extent are specific for a certain service concept. The three classic service concepts in rail freight are Trainload, Wagonload and Intermodal Transport, however, there can also be commodity-specific, customer-specific or otherwise specially tailored service concepts. Production resources are for example locomotives, wagons, personnel, railway lines, yards and terminals, but even organizational structures and train-operating principles (see below).

EVARAIL contains an optimization on the level of individual flows, based on OD-lead time, i.e. it chooses that transport chain within the railway system, which gives the earliest arrival time to D after desired departure time from O. It does not contain a specific optimization routine at the system level.

EVARAIL calculates costs *from the view of a train operator*. Therefore it does not take into account external effects (if they are not internalized, e.g. by infrastructure user fees). Concerning the use of the model in the scientific field one key aspect was to build a model delivering better input data for transport choice and freight transport models.

EVARAIL describes the supply and demand side of rail freight on a detailed level. The model delivers cost data on both rail system and flow/shipment-level..It is general in the sense of being able to depict (almost) every production system and combination of production systems in rail freight, both those used today and potential future systems. By doing so, the model can describe the development opportunities for rail transport systems in a more dynamic perspective, taking into account changes in the rail supply as a result of new production methods, improved technical solutions and operational performance.

The scope of a business-economic model is influenced by the institutional structure of the sector. In the railway industry – as in other industries – this structure is changing over time, and differences also exist between different countries and railway companies. EvaRail is designed in such a way that it to a certain degree can adapt to different institutional models. It allows for example railway companies either to own or to lease/hire production resources (e.g. locomotives). It can also model competition between transport service networks of competing railway companies.

EVARAIL is able to model different train-operating principles for rail freight. The figure below shows some examples of train-operating principles, which can be handled in the model; note that the model is able to depict even combinations of these. These principles are connected with different characteristics in terms of geographical coverage, transport speed and volume demand, which explains, why they are often to some extent combined in the real world.

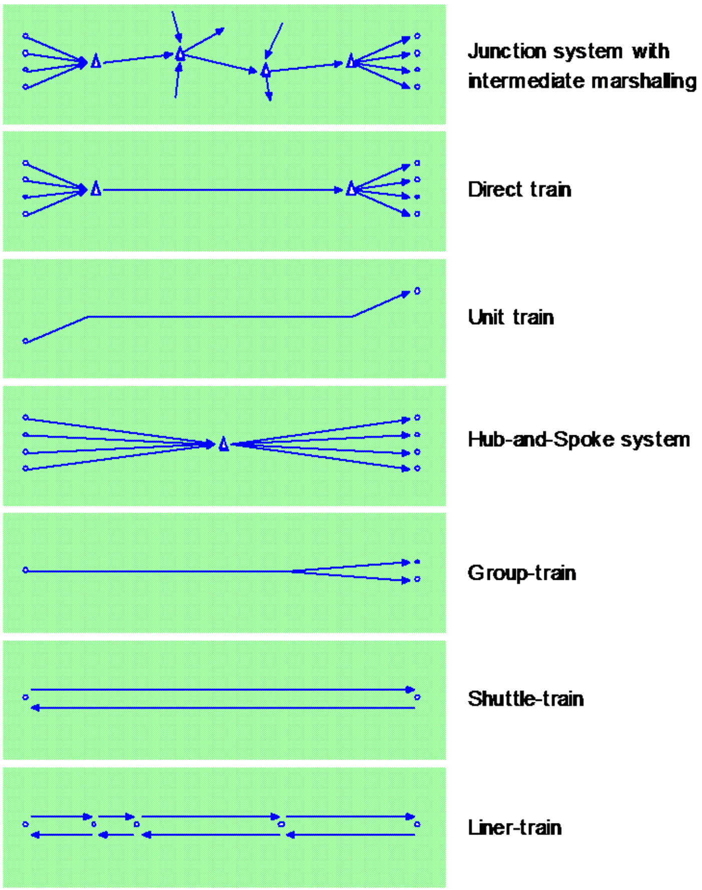

Figure 3 – Train operating principles in rail freight

In EVARAIL the demand side is represented by an OD-matrix for rail volumes in Sweden, while the supply side is represented by the rail network and a detailed definition of train services on this network, including each train path's operational parameters (timetable, traction, maximum length and weight, etc.) and the rail vehicle's technical parameters (loading capacity in ton, cubic-meter and/or cargo-units, length, tare weight, etc.). Seasonal and weekly variations can be taken into account both on the demand and supply side. The model comprises a train building function, avoiding the need to define specific train types; trains are formed of individual wagons within the model.

The following costs together with their main determinants have been included into the model: (1) Capital or rental costs wagons, (2) Maintenance and service costs wagons, (3) Capital or rental costs locomotives, (4) Maintenance and service costs locomotives, (5) Capital or rental costs loading units, (6) Maintenance and service costs loading units, (7) Driver costs, (8) Shunting costs, (9) Marshalling costs, (10) Transloading costs, (11) Infrastructure user fees and (12) Energy costs. The following costs are added as percentage surcharges: (13) administration & planning costs, (14) Overhead costs, (15) Risk costs, (16) Insurance costs and (17) Profit margin. If applicable, even Feeder transport costs (18) can be added.

The rail freight system is depicted in EVARAIL by three main ”levels”, which are interconnected to each other:

- the infrastructure-level
- the train services-level
- the freight flow-level

The *infrastructure* and *train service levels* together represent the *supply side* in rail freight, while the *freight flow level* represents the *demand side*.

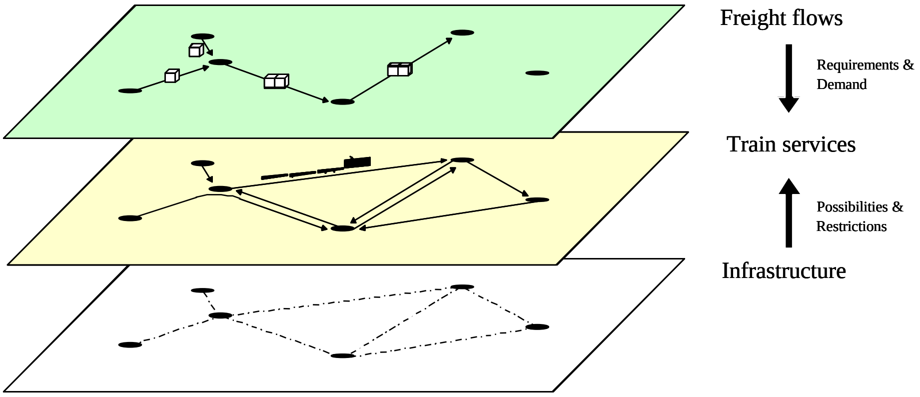

Figure 4 – The three model levels in EvaRail (G.Troche)

The model contains several input-databases: A freight-flow database, a train database, a commodity-database that contains characteristics of the cargo, a vehicle database, a load-unit database and a special cost-database (containing cost-information, which is not contained in other databases, e.g. for personnel, energy, infrastructure access fees, etc.).

Both demand and supply are specified for a whole year with the possibility to vary shipment frequency, shipment size, time windows for loading and unloading, traffic days and a number of other demand and supply parameters over the year. This makes it possible to investigate the effect of weekly as well as seasonal variations on resource utilization and costs.

EvaRail allocates in a first step shipments (freight flows) to wagons (at this stage not yet specifying wagon individuals; this is done in the third step), in a second step wagons to train paths, and in a third step wagon individuals are allocated to each shipment. All allocation steps use a route (train path) choice module, which in the last allocation step (where wagon individuals are allocated to each shipment) even is able to generate necessary empty wagon movements. This route choice module is also used to allocate – in a separate process – traction to trains. For Combined Transport fixed trains can be specified, since wagon turnrounds here are often not linked to specific shipments (i.e. a shipment can use different wagons during a transport, and a train may convey empty wagons (without being an empty wagon movement directly related to a specific future load run; e.g. in shuttle train operations).

In the final step costs are allocated to all resources and calculated for each shipment. EvaRail delivers detailed data both on rail system level and for each individual shipment. In the output-database the total cost of a transport is saved, and all cost components separately and for each section of a shipment. Table II illustrates the high level of detail for the costs calculated in EVARAIIL compared to LOGMOD.

Table II – Overview over cost components in the transport cost calculation in LOGMOD and EVARAIL

LOGMOD	EVARAIL	
		Added as % surcharges
time based (link) costs per trainhour	(1) capital or rental costs wagons	(13) admin & planning costs
	(2) maintenance/service costs wagons	(14) overhead costs
	(3) capital or rental costs locomotives	(16) insurance costs
	(4) maintenance/service costs locomotives	(17) profit margin
	(7) driver costs	
distance based costs (incl link specific infrastructure fees) per trainkilometre	(12) energy costs	
	(11) infrastructure user fees	
loading/unloading and transfer costs I nodes incl shunting/marshalling)	(5) capital or rental costs loading units	
	(6) maintenance/service costs loading units	
	(8) shunting costs	
	(9) marshalling costs	
	(10) transloading costs	
other costs		(15) risk costs
feeder costs specified as other link costs		feeder transport costs can be added (18)

This allows detailed analyses of the cost structure and where in a transport chain costs occur. Output data can also be presented graphically. In addition to cost data the model also delivers detailed data on transport times and train loading factors.

EvaRail is a computer-based model written in VBA (Visual Basic for Applications). Excel worksheets are used to store input and output data, which facilitates further processing, e.g. for graphical presentation or deeper analyses of the data. EvaRail contains some possibilities for graphical presentation.

Table III compares the main characteristics in the LOGMOD and the EVARAIL model.

Table III– Comparsion of main characteristics of LOGMOD and EVARAIL.

	LOGMOD	EVARAIL
Model	Part of National Freight Transport Model system	Rail freight cost model developed at the Royal Institute of Technology Stockholm (KTH)
Perspective	National perspective, mainly developed for policy analysis	Railway undertaking's perspective
Geographical coverage	Transports in, to, from and through Sweden Rail network detailed in Sweden, less detailed outside Sweden	Selected transports in Sweden (project-related) Rail network in Sweden
Modes	All modes	Rail, optionally even road pre- and post-haulage in intermodal transport
Train products	Trainload, Wagonload, Combined Transport. No combination with each other	Trainload, Wagonload, Combined Transport, even in free combination with each other
Train size	Fixed train sizes	Train sizes are calculated within the model individually for each train departure.
Supply	Departure frequencies at O	Train timetable
Demand	PC-flows (all modes), from which OD-flows for rail are derived. Shipment size and frequency are calculated from annual flows in the mode-choice and network assignment step.	OD-flows rail. Shipment size, shipment frequency and desired departure time and day are input-data. Possibility to take into account seasonal variations and time-windows for loading/unloading at O and D.
Commodities	33 based on NSTR	Defined individually, project-related
Consolidation	Within commodities	Train consolidation function; accross flows and commodities
Load units	Containers	Containers, swap-bodies, semitrailers; different sizes
Cost input data	Distance and time-costs for five different vehicle (=train) types	Costs for resources and activities in the rail freight system, see text (ch. EVARAIL)
Programming language	CUBE Delfi	VBA 6.5

Integrated solution

The integrated solution aims at combining the strengths of both LOGMOD and EVARAIL.

LOGMOD's primary role in the integrated solution is to calculate route choice and rail transport demand on OD rail level and to select the best transport chains including rail (rail only or in combination with other modes based) on the annual logistics cost minimization. In the integrated solution LOGMOD can be seen as the "main" model, which uses EVARAIL to obtain more exact cost and transport time information for rail. To do this LOGMOD needs to deliver supply and rail demand data to EVARAIL.

The contribution part of LOGMOD in the integrated solution is to

- to produce OD demand matrices from PC matrices, based on a selection of the best transport chain
- to calculate shipment sizes
- to split mode choice into vehicle choice
- to propose frequencies that EVARAIL can use for timetable-construction
- to calculate logistic cost for all transport chains

The contribution of EvaRail consists in

- a better modelling of the consolidation of freight flows
- modelling of the train-building function
- enabling combinations of different rail production systems
- a better representation of different train operating principles
- a better representation of different loading units and techniques in intermodal chains
- potentially taking into account institutional changes and competition between operators

Some of these aspects are related to each other, both in the real world and when in a modelling context, e.g. is the modelling of the consolidation function, train-building function, production systems and train-operating principles closely related to each other.

In the following it is described more in detail how LOGMOD and EVARAIL are used in main focus areas of the projects to achieve a better modelling of the rail freight system in an integrated solution.

1) Produce OD rail matrices from PC matrices

The logistics model LOGMOD takes as input annual transport demand between production and consumption (aggregate PC flows between zones) and produces OD flows, expressed in tonnes and vehicles for network assignment. The zone to zone flows at the P and C end are disaggregated to firm to firm flows. Logistics decisions like the choice of the average ship ment size for the annual transport volumes between two firms and the level of consolidation are modelled at the firm level. (sew under 2) below).

Sending and receiving firms are described with help of the sizes: small, medium-sized and large firms. This leads to nine combinations (small to small firm, small to medium-sized firms etc.). In addition, very large “singular flows” from one sender to one reveiver can be distinguished separately. Most of the singular flows are rail transports: train load trains that require access to rail at the firm level (and where PC-flow corresponds to the OD-flow). In addition there are large OD-flows between marschalling yards. Within the RAILTRAM-project we make sure that these very large flows are modelled properly and that sensitivity analysis are carried out.

The main contribution of LOGMOD is the connection to the other modes inside and outside Sweden. LOGMOD makes sure the PC-matrices used are based on official statistics for base years and official forecasts for future years. Co-operation and competition between rail and the other modes addressed (which is important to understand developments i.e. the impact of containers for sea transports and the development of facilities in ports in rail transports. (EVARAIL is very specific when it comes to the calculation of costs on the OD-level for rail but does not include the costs for the other components of a firm to firm PC-flow).

Commodity specific results at OD-level are aggregated in order to calculate the total number of trains and other vehicles in the infrastructure network, which is checked against official statistics and other sources.

In order to let both models interact they have to comprise a compatible description of the rail network. Each node in the rail network of LOGMOD needs a corresponding node in the EVARAIL network. (However, EVARAIL also contains nodes, which are not in the LOGMOD network. These nodes are “inactive” when both models are interacting, i.e. they cannot be starting or ending points of transports. Trains can pass them and they are used internally.)

2) Calculate shipment size

Logistic parameters are calculated at the firm level (taking into account if a firm only has only direct access to the road network or also to the rail or sea network. LOGMOD starts from the annual volumes between two firms. Based on an approach that minimizes the total annual logistics costs (transport costs, order costs, ware house costs) the average sizes and transport chains at firm level are calculated in an deterministic approach (a stochastic approach is planned in future). The transport chains are specified for sub modes (i.e. wagon load) that can include several vehicle types (i.e. short wagon load train, medium wagon load train, long wagon load train).

3) Split mode choice into vehicle choice

The logistics model includes different vehicle types per mode, of which seven are trains

- three trainload trains; these trains differ by total weight and can therefore go on different parts of the network (max. axle-load 22,5 ton, 25 ton and 30 ton),
- three wagonload trains; these trains differ by length, which means that specific train sizes require a certain amount of goods for an OD-pair to be interesting from a transport costs point of view
- one container train.

It is only necessary to split the mode choice for wagon load trains in the actual LOGMOD-version which is a large simplification as of real world practices. The train load trains are divided into three sizes according to the part of the network they have access to which is alos a simplification.

4) Consolidation of freight flows across commodity groups

In real world it is more or less the rule that many trains convey wagons for different customers, loaded with different types of commodities – in wagonload and intermodal transport. This feature, leading to economies of scale and scope, is not reflected in LOGMOD. The logistics model LOGMOD does not either include the combination of wagonload wagons and container wagons in one train (see also under 5) for combination of production systems). LOGMOD allows only consolidation of freight flows on OD-level within each commodity group. One reason for choosing this solution (where consolidation is only possible within each commodity) has been the possibility to reduce the run time of the model. Now different commodities can be run in parallel and then merged. To enable LOGMOD to achieve a sufficient level of consolidation the number of commodity-groups has to be kept relative low, so that there is sufficient volume of cargo within each group, which can be consolidated. This means that LOGMOD must rely on a definition of commodity-groups on rather aggregated level, with the consequence that each group may contain commodities of rather varying character in terms of density, stowage-factor, etc.

5) Modelling of combinations of different production systems

While LOGMOD handles Trainload, Wagonload and Intermodal Transport as separate production systems (which compete but do not cooperate with each other) EVARAIL allows all three systems to cooperate. Rather than dividing the rail freight system at high level into three systems, EVARAIL allows to specify on train-path level, for which kinds of transports a train path is open. This is done by defining the types of wagons (classic wagons or intermodal wagons) which can be assigned to a certain train-path. An intermodal train will only be open for intermodal wagons, a wagonload train only for classic wagons; however, a train-path can also be open for both types of wagons. It is also possible to restrict a train-path to certain wagon classes or commodities in order to model trainload and unit-trains or to give priority to certain freight flows and/or commodities.

6) Modelling of the train-building function

Since EVARAIL contains a train-building function based on wagons (and not commodities) it allows also the consolidation of OD-rail flows across commodities (the train-building function is described in the following paragraph). To reflect reality even better, the user may decide to exclude certain commodities for a train-path, e.g. commodities or commodity groups representing dangerous goods. The user can also give priority to specific commodity groups. This may be relevant for example for a train-path destined for a Trainload-service or forming part of a commodity-specific service, where however the possibility should be given to fill up free capacity with single wagons for other transports. This types of priorities require that the user of the model has knowledge about specific situations and potentials.

The train-building function is one of the central characteristics of the rail transport system. The detailed description of the supply side in EVARAIL makes it possible to model the train-building function. In contrast to LOGMOD, which works with few pre-defined train types and train-sizes (see above) and where the transport services are modelled in form of departure frequencies at origin-nodes, EVARAIL works with timetables for train-paths, while the trains themselves are built within the model.

Maximum train-lengths and train gross-weights can be specified individually for each train-path, reflecting the different operational conditions in different parts of the rail network. The actual train-length and train-weight is a result of the network assignment of all shipments. The route choice for shipments/wagons is based on train-path-based transport chains. A train path is “filled” until either the maximum train-length or the maximum train gross-weight is reached. The model chooses that chain, which gives the earliest arrival time after the desired departure time (given that the arrival time lies within a certain by the user specified maximum accepted time-window of each flow). A route choice directly based on costs is not possible in EVARAIL, since the costs are not known before all shipments are assigned; however, since a high portion of costs is time-dependent and the route choice criterium used in EVARAIL ensures a minimum occupation time of the wagons for each shipment, the resulting transport chains can be assumed giving in most cases the lowest or close-to-lowest cost.

Train-building in EVARAIL can take place at the origin-node as well as at one or several intermediate nodes of a transport chain (e.g. marshalling yards along the transport route). The dwell-time of wagons at nodes where train-building takes place depends on the time passing between arrival and departure of incoming and outgoing trains respectively, i.e. is dependent on the timetable and thus – as in reality – varies between different transport chains. Minimum transfer-times can be defined for nodes as well as individual incoming trains. The cost for train-building is specified as a fixed sum per wagon and occasion as far as marshalling (humping) is concerned, and is calculated more in detail as far as shunting is concerned (the relative variation of shunting costs between different places in a railway network is generally higher than those of marshalling costs and has therefore been prioritized in the modelling). Marshalling costs can be defined individually for different nodes (representing different marshalling yards). Shunting costs can be calculated in two different ways, depending on whether shunting is carried out by the train locomotive or by a local shunting engine. In both cases the shunting costs per wagon are dependent on the utilization of the shunting resources and the size of the wagon-group handled in each shunting occasion.

7) Modelling of different train-operating principles and different operators

In EVARAIL it is possible to specify train-paths both with and without intermediate stops. For each stop it is specified, whether one or several of the following activities are allowed:

- Attaching of wagons
- Detaching of wagons
- Loading of Intermodal Loading Units
- Unloading of Intermodal Loading Units

- Transfer of wagons from other trains (requires Attaching of wagons = True)
- Transfer of wagons to other trains (requires Detaching of wagons = True)

For a stop, where the last-mentioned activity – transfer of wagons to other trains – is allowed, a minimum dwell time has to be set by the user, reflecting the minimum time passing between incoming and outgoing trains allowing a connection. EVARAIL also allows to enter for each train-path information about who is the train-operator. Transports can be restricted by the user to use only trains belonging to one or a group of cooperating train operators. With this repertoire of parameters it is possible to model all common types of train-operating principles, including for example local trains in the wagonload-system collecting or setting out wagons at several stations as well as intermodal liner-trains with intermediate stops.

8) Empty wagon movements

LOGMOD works with loading factors for trains and takes in this way into account the effects of empty wagon movements on transport costs. LOGMOD however does not model any empty wagon movements themselves and can neither reflect differences of utilization for wagons used for specific transports.

EVARAIL works with wagon individuals, which are assigned to transports, and consequently needs to model even the empty wagon movements. The user can define on which level the costs for empty wagon movements are allocated to load runs, i.e. to transports. This can be done on wagon-class level or on goods flow level. The latter is preferably used for trainload services in dedicated transport systems.

9) Modelling of different intermodal techniques

As intermodal technique is here considered the specific technical and logistical solution related to the type of loading-unit. The most common types of loading-units are containers, swap-bodies and semitrailers.

In LOGMOD all intermodal transport is modelled based on one standard load unit that is called "container". This means that while port-hinterland traffic where mainly containers are used is reasonably well modelled in LOGMOD and continental intermodal transport, where swap-bodies and semitrailers dominate, is not. Furthermore LOGMOD works only with one container-size. In this context it is important to note that the cost structures are rather different between the different techniques, both when it comes to terminal handling and rail transport (e.g. due to different requirements on terminal handling equipment, different types of wagons and different loading capacity per wagon depending on type of loading-unit).

EVARAIL allows the definition of different types of loading-units as well as different loading unit sizes (e.g. 20ft- and 40ft-containers). EVARAIL also allows the definition of surcharges on capital and maintenance costs for loading-units and on terminal-handling depending on commodity. By doing so the considerably higher costs for loading-units carrying chemicals or foodstuff can be reflected. Currently the type and size of loading-unit used for a specific transport is not chosen within EVARAIL, but is input to the model.

The ambition is to find rules within the RAILTRAM-project which for each OD-rail flow can be used to specify a suitable type of loading-unit and -size. One approach would be to take into consideration for example the type of transport-chain (a transport-chain involving maritime transport would for example mean container-transport), the type of commodity and the total transport-distance (trailer-transport for example has a lower share on very long distances).

10) Taking into account institutional changes and competition/cooperation between rail operators

The institutional and regulatory changes in the rail sector are not reflected in LOGMOD, and are in themselves neither a primary focus of EVARAIL. However, these changes are affecting the rail freight system in two ways:

One way is the emergence of geographically overlapping, competing train service networks. Shipments (and empty wagon movements) cannot move freely between service networks (= trains) of different operators, affecting route choice and rail transit times. EVARAIL takes this circumstance into account and allows the user to specify the operator of a train-path. By doing so wagons can be prevented from becoming assigned to trains of competing operators during a transport. The model may be in the future further refined, for example by allowing exceptions for certain trains, at certain nodes or for certain types of transport, in order to reflect the concept of “co-opetition”, meaning that train operators may compete in certain parts of the transport market, while competing in others.

Another way the institutional changes are influencing the rail freight system concerns the calculation of costs. Traditionally railway undertakings owned most of their production resources. As mentioned above, the emergence of new railway undertakings with new business models has led to other arrangements, based on lease and hire, gaining in popularity. In EVARAIL the user can define for individual train-operators, whether owned or leased resources are used. It should be noted that this choice is not done by the model but by the user. Thus EVARAIL is not intended to identify the “best” solution (i.e. whether to own or lease/hire the resources), but rather to reflect the actual solution chosen by different operators. Including both options in EVARAIL also helps to facilitate the gathering of (cost) input data to the model. This information could be used in the development of different scenarios or in order to validate data used in LOGMOD.

There is no information about competition between rail operators in LOGMOD; but possible effects on route choice, rail transit times and cost calculation can be taken into account within EVARAIL and thus included in the cost, route and transport time data which EVARAIL submits to LOGMOD.

11) Combining train frequencies and timetables

The representation of transport services is in EVARAIL time table-based and in LOGMOD frequency-based. Within the RAILTRAM-project a routine will be developed to derive departure frequencies from EVARAILs timetables, which is a relatively easy task from a modelling point of view.

More challenging is the task to derive default timetables from frequencies in LOGMOD, so that the supply description in LOGMOD can be expressed in a way which can be used in EVARAIL. Such a routine will have to be based on assumptions of preferred departure times, but also needs to take into account the rail network. In LOGMOD several stations along a railway line can have a departure frequency, however, LOGMOD contains no information, whether these belong to the same train, or whether these are separate trains. It has also to be defined where a train-path starts and ends.
To derive timetables from LOGMOD's departure frequencies will thus require a comprehensive set or rules.

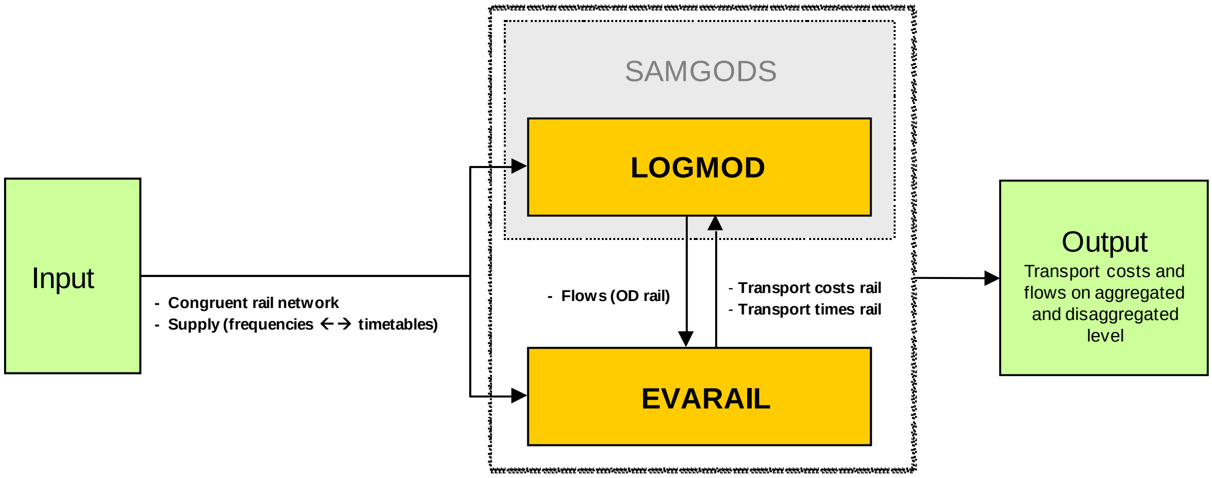

Figure 5 – Illustration of Integrated Solution

Further development

Within the RAILTRAM-project a number of areas for further improvement and development have been identified, which however would by far exceed the frame of the current project. They are therefore only shortly mentioned here in order to highlight some ideas which may become subject of upcoming projects. Above that there is work going on to develop LOGMOD and EVA-RAIL in other areas (like user interface for LOGMOD) which is not addressed here.

One area of further development is the connection to a traffic simulation model. This would allow to take into account infrastructure capacity in links and nodes more exactly and also to test the feasibility of fictive timetables. It can be said that the integration of LOGMOD and EVARAIL already paves the way for a later integration with a traffic simulation model, since EVARAIL already works with exact timetable-data, a precondition for handling the supply side in a traffic simulation model.

Another area for further development may be to use more output-data from EVARAIL in the integrated solution. Currently only cost data and rail transport times are planned to be transferred from EVARAIL to LOGMOD. However, EVARAIL also produces more exact data on the route choice within the rail network. To include this information in LOGMOD would increase the possibilities for analyses on geographically disaggregated level. Transport time and route choice are related to each other and should thus be so even in a modelling context.

CONCLUSIONS

Though the project is not finished yet a number of conclusions can be drawn from work carried out so far, allowing to give some answers to the research questions identified earlier:

1) **How to calculate transport costs in rail freight and intermodal transport chains on disaggregated level?**
   The key for a better calculation of rail transport costs on disaggregated level is a more detailed modelling of the rail freight supply, reflecting the variety of different production systems and methods. The experience with the Swedish National transport model has shown that this requires to take more specific into account how rail freight is modelled. Since the rail freight system is in the real world characterized by a higher complexity than other transport systems, it is inevitable that even the description of this system in a model necessarily becomes more complex than that of other transport modes. Important in this context is that the modelling approach for rail freight depicts unique characteristics as the train building function. Doing this opens up the possibility to model the transport service network(s) for rail freight in much more detail, allowing a better calculation of rail transport times, consolidation within the railway system, a better route choice, a better quantification of the use of economies of scale and scope and in the end a more exact calculation of transport costs and assignment of freight flows. The EVARAIL model developed at the Royal Institute of Technology has these features and it has therefore been decided to use EVARAIL to support LOGMOD, when it comes to the calculation of transport costs.

2) **How to improve the consolidation function and the modelling of service networks in the in the national logistics model?**
   There are three prerequisites to model consolidation within the railway system: One is the ability to consolidate across commodities, since a train often convey wagons belonging to different transports and with different commodities. The second is that the modelling of rail transports should be done on wagon level as smallest transport unit in the rail freight system (instead of train level, as currently in LOGMOD). The third prerequisite is that the transport service networks have to be depicted in the model on train level. In the outline for an integrated solution presented in this paper this has be done with a timetable-based approach. Theoretically even an approach based on train-frequencies (but not only departure frequencies like in LODMOD) would be sufficient in order to model the train formation function (however a timetable-based approach has the advantage to give more reliable results on disaggregated level).

3) **How to take into account different intermodal transport techniques?**
The three dominating intermodal transport techniques – containers, swap-bodies and semitrailers – have different costs and cost structures, resulting from their specific technical characteristics, their requirements on rolling stock and terminal handling and their logistical capabilities. Costs are also influenced by loading unit size. EVARAIL therefore contains both all three types of loading units as well as different sizes. Currently the user still has to define the type and size of loading-unit used for a certain transport, however, ideas have been developed within the RAILTRAM-project to develop a routine allowing the model to carry out this decision, taking into account characteristics of a goods flow, e.g. combination with other transport modes, total transport distance and commodity.

4) **How to handle the influence of institutional and regulatory changes in the rail sector on supply, production and pricing of rail freight services?**
The institutional and regulatory changes in the European rail freight sector have led to the emergence of geographically overlapping, competing rail transport service / service networks. They have also influenced the way how costs are calculated within railway undertakings, e.g. as a result of increased popularity of leasing instead of owning of key production resources. Thus there is an impact both on the supply side (rail transport times and route choice), as well as on costs and cost calculation. These circumstances can be taken into account in EVARAIL, which allows the user to specify different operators for different trains, thus avoiding transports to move freely between different operator's networks, as well as the usage of owned or leased/hired locomotives, wagons and personnel, reflecting the different ways in which railway undertakings have to calculate their costs.

5) **How to reflect the different transport cost structures for different commodities due to their specific physical characteristics?**
Here it is important to take into account the density or stowage factor and logistical requirements of different commodities. Ideally a model should not work with average payloads per transport unit (e.g. wagon or intermodal loading unit), but calculate individual payloads for each commodity. EVARAIL allows the user to define either the density of a cargo or its stowage factor. For each commodity is also indicated whether it has a smallest indivisible unit or not. The transport capacity of freight wagons is always given in ton, but – where applicable – even in cubic-metres and number of (indivisible) cargo units. Thus EVARAIL allows to calculate the payload of a wagon or intermodal loading-unit based on both the physical characteristics of the commodity as well as the transport capacity of the wagon or loading-unit.

The RAILTRAM-project has shown so far that there are various ways to go further in the disaggregate-aggregate-disaggregate approach to improve the modelling of rail freight in the national Swedish logistics model LOGMOD by using the Swedish EVARAIL-cost model. We are though aware of the trade-off between level of detail and number of loops to be performed between LOGMOD and EVARAIL and the applicability in the transport model for policy analysis.

The project analyses which changes are required in the LOGMOD and EVARAIL to be able to co-operate and where and how interfaces between the models should be developed and will identify which improvements should be prioritised from a policy analysis perspective and from a modelling perspective degree of difficulty. Also the trade off between level of detail and run time will be studied and the possibility to choose different aggregation levels when performing policy analyses.

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