A Methodological Framework for Analyzing Rail Freight Planning

Stephan Moll (corresponding author)
Swiss Federal Institute of Technology (ETH)
Institute for Transport Planning and Systems (IVT)
Wolfgang-Pauli-Strasse 15
8093 Zürich
Switzerland

tel + 41 44 633 31 92
fax + 41 44 633 10 57
e-mail moll@ivt.baug.ethz.ch
www http://www.ivt.ethz.ch/people/smoll

Prof. Dr. Ulrich Weidmann
Swiss Federal Institute of Technology (ETH)
Institute for Transport Planning and Systems (IVT)
Wolfgang-Pauli-Strasse 15
8093 Zurich
Switzerland

tel + 41 44 633 33 50
fax + 41 44 633 10 57
e-mail weidmann@ivt.baug.ethz.ch
www http://www.ivt.ethz.ch/people/ulrichw/index_EN

Andrew Nash
Vienna Transportation Strategies
Bandgasse 21/15
1070 Vienna
Austria

tel + 43 676 933 0483
e-mail andy@andynash.com
www http://www.andynash.com/

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ABSTRACT

The freight transport business is extremely challenging for railways since truck transport has intrinsic advantages with respect to flexibility and quality. Providing customers with flexible scheduling is particularly hard since optimizing an interconnected rail operating plan is much more difficult than arranging for shipment by truck. In this environment it would be very helpful if shippers could provide railways with accurate demand forecasts. However, the ability to forecast rail freight transport differs strongly between shipping companies and commodity types.

The goal of this research is to develop a methodical framework to better understand the characteristics that influence the ability of freight shippers to prepare high quality forecasts of rail demand. This information will help railways increase productivity by improving their ability to develop optimized schedules. It will do this by helping them decide when to rely on shipper forecasts and as a benchmark to identify shippers that can provide high quality forecasts.

The paper describes the methodological framework and presents results from a case study application to illustrate the practical applicability of the proposed framework.

1. INTRODUCTION

The freight transport business is extremely competitive. It is particularly challenging for railways since truck transport has certain intrinsic advantages with respect to flexibility and quality. As a result railways are faced with a difficult balancing act between providing flexible customer solutions and operating at high productivity – in addition to strong pricing pressure.

The requirement for providing customers with flexible scheduling is particularly difficult for railways because it is much more complicated to optimize rail operations than it is to simply provide a truck. In Switzerland, for example, shipping companies often order block trains on a weekly basis. This leaves the freight railway with only a few days for creating timetables and duty schedules.

In this environment it would be very helpful if freight shippers could provide railways with accurate demand forecasts so the railways could optimize resource planning. However, the ability to forecast rail freight transport differs strongly between companies and commodity types.

The goal of this research is to develop a methodical framework to better understand the characteristics that influence the ability of freight shippers to prepare high quality forecasts of rail demand. Understanding the quality of company-provided rail demand forecasts can help railways increase productivity by improving their ability to develop optimized schedules. Furthermore, the results can be used as a benchmark to identify shipping companies that have the ability to provide high quality forecasts. Railways can use this benchmarking information to request forecasts from companies with the potential for providing high quality forecasts, and can adjust service provisions for companies that have lower potential for providing high quality forecasts.

The next section describes the approach used for developing the methodological framework. Section 3 describes the framework and the framework characteristics in detail. Section 4 describes a case study application of the framework and Section 5 presents conclusions.

2. METHODOLOGY AND DATA COLLECTION

The proposed framework for analysing and describing rail transport planning at shipping companies is based on the concept of morphological analysis. Fritz Zwicky developed morphological analysis in the 1940es as a method “for structuring and investigating the total set of relationships contained in multi-dimensional, non-quantifiable, problem complexes” [1].

The basic idea of morphological analysis is to break a subject down into a set of fundamental features that describe the subject as completely as necessary to solve a specific problem [2]. Next, the possible values for each feature are identified. This approach ensures that morphological schemes show the full range of possibilities and that no possibility is neglected. This enables planners to complete a structured and comprehensible analysis of complex problems.

Morphological analysis has been applied to many diverse subjects. In the field of logistics morphological schemes have been created to describe both in-house logistic planning [3] and to characterize supply chains between manufacturing companies [4]. The goal of this research is to create a morphological scheme focusing on freight rail transport planning.

The basic structure of the proposed morphological scheme was derived from the Supply Chain Planning Matrix [5]. An adapted version of this matrix is illustrated in Figure 1.

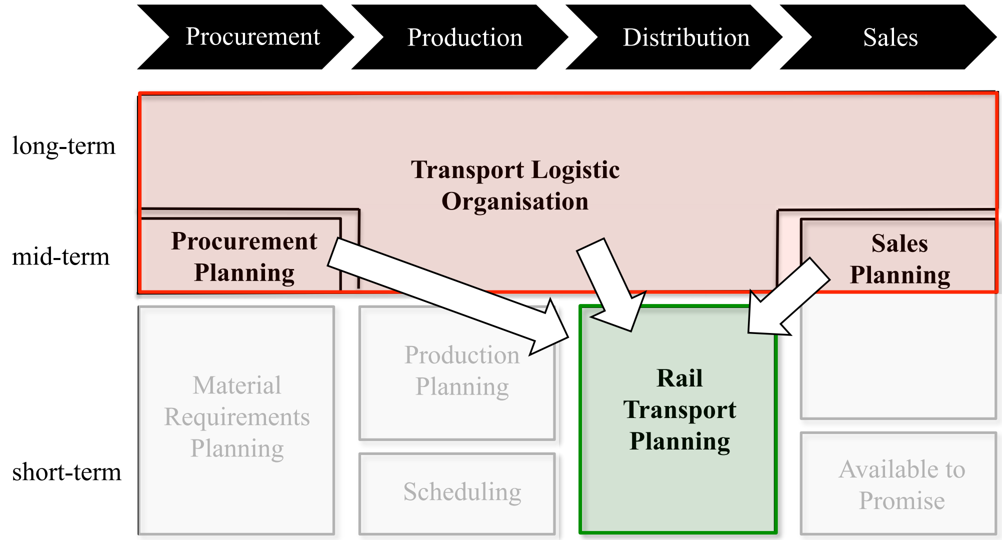

FIGURE 1 Main areas with relevance to transport planning.

Three main categories from the matrix are especially relevant to rail freight transport planning:

- **transport logistics organisation** – defined as the infrastructure and organisational limits for transport planning; typical examples are stock capacities and the geographical distribution of goods being shipped;
- **sales/procurement planning** – essentially the pre-cursors to transport demand; vague sales/procurement estimates significantly impact the quality of transport forecasts (note that the choice of whether sales or procurement forecasts need to be considered depends on who is responsible for making the shipping decisions: the supplier or the receiver); and,
- **rail transport planning** – this includes many factors ranging transport flexibility to the form and quality of forecasts and orders.

In this research the most relevant features in these three categories were identified based on expert interviews and literature review. The literature provided important clues on constraints influencing transport logistics including the production process, stock capacities, and transport relations [6], [7]. While a series of in-depth personal interviews with transport experts from a large Swiss freight railway and eight representative rail-shipping companies were the main source of information. The companies are located in Switzerland and operate in very different sectors including mineral oil, gravel, and iron & steel.

The next section describes the proposed morphological framework and characteristics in more detail.

3. PROPOSED MORPHOLOGICAL FRAMEWORK

The proposed morphological framework is organized in terms of category, sub-category, feature and values. The research goal was to identify the feature values that are "more likely" to lead to accurate shipping forecasts by the shippers. Railways could then use this information to determine the ability of shippers to prepare high quality forecasts and to help determine customer specific service strategies (e.g. pricing, service frequency, etc.). This information, in turn, can be used to help optimize railway schedule development.

In the tables, the values for each feature are arranged so that the railway's expected probability for receiving a high quality forecast from the shipper increases from left to right.

3.1 Transport Logistic Organisation

There are three key elements of transport logistic organization that impact rail freight planning: transport network structure, transport responsibility and transport origin/destination. These elements and their features are outlined below and summarized in Table 1.

TABLE 1 Transport Logistic Organization: Features and proposed values.

Sub-category	*Feature*	*Value*			
Transport Network Structure	Number of origins	> 15	6 – 15	2 – 5	1
	Number of destinations	> 15	6 – 15	2 – 5	1
	Percentage of total transport volumes on the 20% most important relations	< 50%	50% – 60%	60% – 70%	> 70%
	Network extent	international / long-distance		domestic / short-distance	
Transport Responsibility	Number of railways involved	several		one	
	Provider of shipping-paid deliveries	yes		no	
	User of shipping-paid deliveries	no	yes, partly		yes
	Entity responsible for releasing products being shipped	≠ freight payer		= freight payer	
Transport Origin	Quantitative flexibility of production capacity at origin	flexibel in terms of time	hardly flexible in terms of time		not flexible in terms of time
	Inventory philosophy at origin	high inventory	medium inventory		minimum inventory (just-in-time)
	Entity in charge of origin site	≠ entity placing shipment order		= entity placing shipment order	
	Use of rail siding	exclusive		shared	
Transport Destination	Quantitative flexibility of production capacity at destination	flexibel in terms of time	hardly flexible in terms of time		not flexible in terms of time
	Inventory philosophy at destination	high inventory	medium inventory		minimum inventory (just-in-time)
	Entity in charge of destination site	≠ entity placing shipment order		= entity placing shipment order	
	Use of rail siding	exclusive		shared	

3.1.1 Transport Network Structure

The structure of the transport network has a fundamental effect on transport planning; put simply, the more complex the network, the more challenging is the planning. Table 1 presents the four transport planning features identified in this research for use in characterising a transport network:

- Number of origins
- Number of destinations
- Percentage of transport on top 20% relations
- Network extent

The first two features are obvious. The simplest transport network consists of one origin and one destination. Network complexity increases with the *number of origins* and *destinations*. Therefore the best situation for making forecasts is when there is only one possible origin and one possible destination (shown by the value 1 being placed at the right-hand side of the table).

The third feature is concentration of freight traffic. Transport planning is less complex if a shipper's transport is concentrated on a few specific origin-destination relationships. Concentration can be measured by the distribution of transport volumes on specific transport relations. The proposed feature is the *percentage of total transport volumes on the 20% most important relations*. Although this measure does not show the exact distribution function of transport volumes, it gives an accurate indication.

The fourth feature for characterising transport network structure is its extent. A network comprising long-distance and/or international transport relationships is generally more challenging for transport planning, because the chance of delays increases with longer distances and border crossings.

3.1.2 Transport Responsibility

As shown in Table 1, transport responsibility consists of four main features impacting transport planning. The first feature is the *number of involved railways*. In Europe this is mainly relevant in international shipping. Although Europe's liberalised rail freight market allows railways to run trains in several countries, often this is not economically feasible and several railways are involved in completing the transport.

The more railways involved in the transport process the more complex the planning since there is a high potential for delay when handing over trains (especially at national borders) and different railways have different punctuality standards. Furthermore, delays to one shipment may force companies to make short-term changes to other planned shipments to ensure adequate supply/distribution throughout the logistics chain; this further increases transport planning complexity.

The second feature of transport responsibility is the *use of shipping-paid deliveries*. Shipping-paid deliveries are freight shipments where the entity ordering the product being shipped does not order the transport service from the railway (instead the entity shipping the product orders the service). In this case forecasts from the entity ordering the product would not include the transport. In an ideal world the shipment would be forecasted by the company shipping the product, but in reality many companies use shipping-paid deliveries to meet peak demand and therefore it is difficult to forecast these shipments.

In short, being a user of carriage-paid deliveries might be economically profitable for companies if they can be responsible for planning transport of basic demands and they can use carriage paid deliveries cover peak demands. This strategy has a stabilizing effect on the transport planning for these companies but has the opposite effect for *providers of shipping-paid deliveries*. Their planning tends to become less stable and predictable.

The fourth feature is *entity responsible for releasing product being shipped*. This is the entity that actually releases the freight shipment. If the entity releasing the shipment is also the entity ordering the transport service then its ability to provide good forecasts to the freight railway is higher than if the entity ordering the service does not control release of the shipment.

3.1.3 Physical Characteristics at Transport Origin and Destination

The third sub-category of Transport Logistic Organization is the physical situation at the transport origin and destination. As illustrated in Table 1 the same features and values are proposed for both origins and destinations.

Transport origins and destinations can be either storage facilities or production sites. In both cases the ability to buffer demand for transport service through either storage facilities or as part of the production process influences the predictability of transport planning forecasts.

The first feature is *quantitative flexibility of production capacity*; this describes the temporal flexibility of production capacity [3]. All other things being equal, a more flexible production capacity reduces the ability to forecast transportation demand precisely.

The second feature is storage capacity. This feature is described in terms of the *inventory philosophy*. Inventory philosophy describes an aggregated set of storage depot characteristics from the perspective of transportation planning (since management of storage depots is a very complex optimization problem, the measure proposed in this research ignores aspects of storage depot management that do not directly impact transportation planning). This research defines three levels of inventory philosophies:

- **Minimum inventory** – Storage depots with a "minimum" inventory are highly dependent on regular and/or accurately planned transport. Therefore the quality of forecasts from storage facilities with minimum inventory are generally very high since any deviations from transport schedules would risk a shortage or overflow of inventories within days. This is typically found at companies following a Just-in-Time strategy, which invests in logistics, production techniques and training of personnel to minimize inventories.
- **Medium inventory** – Storage depots with a "medium" inventory have more transport flexibility than those with minimum inventory, therefore their transport forecasts tend to be less accurate (since, e.g. production does not need to be shipped away immediately).
- **High inventory** – Storage depots with a "high" inventory provide extreme transport planning flexibility since their high capacity means they do not require regular supply or demand transport.

For production sites transport demand forecasts are expected to be stable if production is not flexible in terms of time and there is a miminum inventory storage capacity available. In this case, production output must be shipped away immediately. Production sites with little quantitative flexibility are typically found in process industries (e.g. refineries).

For storage sites, the storage capacity is the only relevant feature. Transport demand forecasts are expected to be stable if there is little storage capacity.

The third transport planning feature impacting forecast accuracy is the *entity in charge of transport site*. If the entity ordering service also controls the transport site, there is a higher chance of a coordinated planning of production, inventory, and transport. This coordination helps ensure that requirements for achieving stable and accurate transport plans are more likely to be considered in inventory and/or production planning decisions, and therefore forecasts should be accurate.

On the other hand, if the entity in charge of the transport site is not the entity providing the forecasts there is a risk of unilateral inventory or production optimisations at the expense of transport forecasting accuracy. This especially applies if the entity in charge of the transport site is in a dominant position towards the entity responsible for ordering the transport service. Note that while generally the entity ordering service will be either at the origin or destination, there are also cases where the same entity can be at both ends of the trip chain.

The last physical characteristics feature is *use of rail siding*. Shared use of rail siding forces companies to carefully plan their shipment loading/unloading time slots. This need for cooperation reduces short-term flexibility of transport planning which means forecasts coming from companies that share sidings should be more accurate.

3.2. Sales/Procurement Planning

The second category of information is sales/procurement planning. In practice analysts consider either sales or procurement planning, depending on who is ordering the transport service. If the shipper is ordering service sales planning is considered and if the purchaser is ordering service procurement planning is considered. There are two sub-categories: freight customer service characteristics and sales/procurement plan. Table 2 presents the features and values for sales/procurement planning.

TABLE 2 Sales/Procurement Planning: Features and proposed values.

Sub-category	***Feature***	***Value***		
Freight Customer Service Characteristics	Shipment lot size	block trains	freight wagons	
	Delivery date flexibility	± 1 week or more	± 1 day	not flexible
Sales / Procurement Plan	Time horizon	< 1 week	≥ 1 week	≥ 1 month
	Level of detail	month	week	day
	Forecast technique	intuitive	mathematical	none (firm orders)

The first freight customer service characteristic feature is *shipment lot size*. The larger the shipment lot size, the more it affects rail transport planning. Large shipments are made using block trains, modifying these orders often necessitates rescheduling shipper and carrier transport plans. Changes to smaller lot sizes, for example single wagonload service, typically have a small impact on scheduling due to the large number of possibilities for adding a freight wagon to another train.

The second feature is *delivery date flexibility*. If delivery dates are not flexible, transport planning lacks an important option for optimisation; on the other hand, transport forecasts become more stable, because there is no possibility to modify delivery dates at short-notice.

If delivery dates are flexible, it is possible to optimise scheduling by making short-term modifications, however these short-term modifications do not necessarily increase the potential for increased rail transport system optimisation. Quite in contrary, flexible delivery dates could be a sign that a shipper cannot determine an exact delivery date (e.g. goods being shipped are loaded but awaiting results of quality tests). In this case, transport planning at the railway would be reduced to a day-to-day activity with no dependable planning horizon.

The second sub-category is the sales/procurement plan itself. This plan is the shipping company's forecast of product sales or procurement, so it is the precursor to transport forecast and therefore is a major source of information for transport planning. The sales/procurement plan has three features: the forecast *time horizon, level of detail*, and *forecast technique.* The values of these features are influenced by numerous factors including volatility of demand, flexibility of sales terms, and intensity of collaboration between customer and shipper.

The time horizon and level of detail values reflect the reasonably achievable accuracy in sales/procurement planning. As shown in Table 2, the longer the forecast time horizon and the more precise the level of detail (i.e. a daily forecast rather than a monthly forecast) the better.

The third feature, demand estimation technique*,* has three possible values: intuitive forecasts, mathematical forecasts and firm orders. Sales or procurement forecasts developed using mathematical forecasting techniques (which imply the existence of a quantifiable future demand behaviour [3]), are generally more accurate than those made for irregular or sporadic demands (typically intuitive forecasts). The highest accuracy is expected if planning can rely on firm orders only. No forecast would than be necessary.

It is important to note that an accurate and long-term sales/procurement plan generally leads to an accurate and long-term transport plan too. However, the reverse argument is not necessarily true. Transport planning can be accurate even if underlying sales/procurement plans are uncertain. However, in this case the shipping company must have many transport planning options available to manage demand deviations, which they can use to reduce the need for changes to the planned transport schedule (see Section 3.3.2).

3.3. Transport Planning

The third category of information is transport planning. It considers the transport plan, the transport flexibility, the forecast information provided to the freight railway and the order information. These four sub-categories and their proposed features and values are presented in Table 3.

TABLE 3 Transport Planning: Features and proposed values.

Sub-category	***Feature***	***Value***			
Transport Plan	Time horizon	< 1 week	≥ 1 week		≥ 1 month
	Level of detail	month	week		day
	Revision cycle	daily	event-driven	weekly	no revision
Transport Flexibility	Availability of transport alternatives at short notice	yes		no	
	Latest possible time for placing transport order	≤ 1 day prior to shipping	≤ 1 week prior to shipping		> 1 week prior to shipping
	Transport vehicle ownvership	ad-hoc leasing		proprietary possession / long-term leasing	
	Non-transport measures for adressing demand deviations	none	few		many
Forecast information provided to the freight railway	Forecast accuracy	< 80%	80% - 85%	85% - 90%	> 90%
	Share of shipments forecasted	< 50%	50% - 75%	75% - 90%	> 90%
	Forecast frequency	irregular	monthly	weekly	daily
	Forecast time horizon	≤ 1 week	2 - 3 weeks		≥ 1 month
	Forecast level of detail	month	week		day
Order information	Order accuracy	< 85%	85% - 90%	90% - 95%	> 95%
	Dominant type of order change	cancel shipment	change date	change destination	additional goods to transport

3.3.1 Transport Plan

The transport plan is prepared based on the company's sales/procurement. It is important to consider the transport plan separately because it is often made from a shipper's perspective without considering needs of transport service providers.

The first feature of transport plan is *time horizon.* It reflects the optimal time horizon for transport planning from the shipper's perspective. For the railway the longer the time horizon the better.

The second feature is *level of detail.* This is an indicator of planning uncertainty. Transport plans that forecast demand on a monthly or weekly level are generally more uncertain than plans that specify daily demand. Highly aggregated forecasts are generally of little or no value for freight railways.

The third feature is the *revision cycle*. In the best case there would be no revisions (indicating stable transport forecasts), while daily revisions would be the worst case (indicating highly unpredictable transport demand). In the middle are weekly plan revisions and event-driven plan revisions (e.g. due to unexpected sales or production breakdowns). Event driven plan revisions are almost as bad as daily plan revisions because they also make very short term changes to schedules.

3.3.2 Transport Flexibility

The transport flexibility sub-category consists of physical and operational characteristics of the shipper that influence its ability to make accurate transport forecasts.

The first feature is the *availability of transport alternatives at short notice*. There is little incentive for shippers to create accurate long-term rail transport plans, if they have alternatives at short-notice. Stable long-term rail transport plans can be developed if rail is used to meet basic transport demands, while other transport modes are used to meet peak demand. The reverse strategy would reduce forecast accuracy.

The second feature is *latest possible time for placing transport order*. This feature reflects the fact that railways face strong competition from trucking, a mode that offers extreme scheduling flexibility. Therefore railways must offer schedule flexibility to be competitive. The values for this feature range from one-day-or-less to over-one-week. The shorter the allowable time horizon for ordering service, the less need for shippers to develop accurate forecasts.

The third feature is *transport vehicle ownership*. This feature considers the ability for shippers to adjust the number of freight wagons available for their use at any given time. The most accurate forecasts are made by shippers using their own exclusive wagon fleets (either owned or leased) since this places a limit on the maximum possible number of shipped wagons or block trains possible even if higher demand existed. Shippers operating their own wagon fleets also have a direct financial interest in maximizing fleet utilization, which is only possible with a stable and predictable transport schedule.

On the other hand, when shippers lease freight wagons on an ad-hoc basis their schedule forecasts are less predictable. Ad-hoc leasing is very common in single-wagonload services and can be arranged very quickly. In Switzerland, for example, shippers can order freight wagons one workday in advance [8]. This enables shippers to rapidly adjust their shipping according to actual demand. Without incentives for early wagon reservations, shippers have little incentive to develop stable long-term transport plans.

The final feature is availability of *non-transport measures for addressing demand deviations*. The more non-transport related measures are available, the more stable the transport plans. These measures differ significantly between product sectors and even within sectors. An example of a non-transport related measure is the ability to rent additional storage capacities on a short term basis to avoid the need for cancelling a shipment if the company's own on-site storage facilities are full.

3.3.3 Shipper Forecast Information

The third sub-category of transport planning is the quality of forecast information provided by the shipper to the freight railway. In this research forecasts are defined as non-binding plans while orders involve a financial penalty for changes. As shown in Table 3, there are five features of forecasts.

The most important feature is *forecast accuracy*. It is defined as ratio of the number of changes of predicted shipments to the total number of predicted shipments. A change can be a cancellation, a change of destination, or a change of shipment date. In talks with production planning experts from a large Swiss freight railway, forecasts having an accuracy of less than 80% are generally either not transmitted to freight railways or otherwise not considered by the railway in production planning.

The second feature is *share of shipments forecasted*. This reflects the accuracy of forecasting the quantity of goods to be shipped. If the share of shipments forecasted is >90%, this means that over 90% of the shipped quantity of goods was actually forecasted. Low percentages indicate that the shipper regularly underestimates the quantity of goods to be shipped. Generally over-estimates are worse for the railway because it means that resources are assigned but not needed.

The third feature is frequency of forecasts provided to the freight railway. A high and regular *forecast frequency* is better for the railway because it means the railway has up-to-date information about expected future transport demand. Similarly, for the last two features in this category: a long *forecast horizon* and a high *level of detail*, are best for predicting the quality of demand forecasts provided that accuracy remains acceptably high.

3.3.4 Shipper Order Information

The final sub-category of information regarding transport planning is the quality of order information. While shippers do not want to change orders since they will incur a financial penalty sometimes it is necessary. A freight railway's acceptance of order changes and extra orders is a gesture of goodwill and an important negotiating point. As shown in Table 3 there are two main features of order information.

As with forecast information the most important factor for orders is *accuracy*. The accuracy of shipment orders is defined as ratio of the number of changes made to shipment orders + additional shipment orders divided by the total number of shipment orders placed.

The second feature is *dominant type of order change*. This feature reflects the fact that not all types of order change have the same implications on railway scheduling. The most favourable changes are extra orders placed after the due date. They generally improve railway production plans since railways are free to reject these requests when they do not have adequate capacity.

Changes of destinations generally have minor implications on railway production planning as long as a major part of the initial itinerary remains unchanged. Changed shipping dates directly affect production planning, but their significance depends on the particular planning situation; therefore their impact is not generally assessable. Order cancellations are the worst possible situation for the railway because the revenue is lost but the costs for personnel and rolling stock (which cannot be redeployed in the short-term) remain.

4. CASE STUDY

The proposed framework was tested in a case study of a company that ships refined mineral oil products (fuel and heating oil) in block trains (primarily) from a refinery to large distribution depots in Switzerland. The shipping volume is approximately 20 loaded block trains per week. This classifies the company as a large-scale shipper in Switzerland. The case study analysis is based on a face-to-face interview with the company's manager of rail transport planning and detailed forecast and order data from the company (covering all block trains during 2009).

Table 4 summarizes the characteristics of forecasts and orders from the company. As shown in the table, the company forecasts are very helpful for the railway. More than 75% of total shipments are forecasted on a detailed level and these forecasts have a very high accuracy (over 90%). The company regularly transmits forecasts to the freight railway at the end of each month for the entire upcoming month. During the month, there are few event-driven updates of this monthly forecast. This forecast quality is unsurpassed when compared to other companies shipping mineral oil in Switzerland. The accuracy of transmitted orders one week prior to shipping is close to 100%. The few subsequent changes of orders and forecasts primarily concern cancellations.

TABLE 4 Forecast and order information transmitted by a large mineral oil company in Switzerland to its freight railway.

Sub-category	*Feature*	*Value*			
Forecast information	Forecast accuracy	< 80%	80% - 85%	85% - 90%	> 90%
	Share of shipments forecasted	< 50%	50% - 75%	75% - 90%	> 90%
	Forecast frequency	irregular	monthly[1]	weekly	daily
	Forecast time horizon	≤ 1 week	2 - 3 weeks		≥ 1 month
	Forecast level of detail	month	week		day
Order information	Order Accuracy	< 85%	85% - 90%	90% - 95%	> 95%
	Dominant type of order change	cancel shipment	change date	change destination	additional goods to transport

[1] some event-driven updates of monthly forecast during months

The research goal is to identify the features that help companies make accurate forecasts. Therefore the case study company's feature values in the proposed morphological framework should be clustered on the right side of the tables. Table 5 summarizes the case study company's feature values.

Interestingly, the company has a reasonably complex transport network with 2-5 origins and more than 15 destinations. Furthermore, the percentage of total transport volumes on the 20% most important relations is 60%-70%. This suggests a heterogenic distribution of transport through the network. The network extent is limited to Switzerland, which reduces complexity.

A problem for the company involves low sales planning accuracy reflected by the fact that the company relies on intuitive heating oil sales forecasts produced on a monthly basis. The problem is that, in contrast to fuel demand, heating oil demand is very difficult to predict. There are several reasons for this including high customer price sensitivity, a time shift between sales and physical delivery of heating oil to end customers and weather. Therefore sales estimates of heating oil demand are made intuitively requiring sound expert knowledge.

However, there are several important reasons why this company is nevertheless able to forecast their rail transport demand accurately. First, the large majority of the company's rail transport depart from their own refinery. The refinery's flexibility of production capacity is very limited, meaning that only minor modifications in production output are possible within a weekly time period. Furthermore, the buffer function of production output depots at the refinery is low. This is supported by the fact that the inventory accounting at the company refinery is done at production input level only. Hence, products must be shipped to distribution depots quickly, regardless of actual demand.

Second, the company's transport flexibility is limited. The company leases their rail tank wagons in long-term contracts. Therefore transport capacities remain constant within a period of at least several months and the company has an immediate financial interest to fully utilize their leased railcars. This requires regular and stable shipment intervals, which is highly congruent with the interests of freight railways.

Fixed transport capacities also limit the maximum number of shipments at times of peak demand. This requires the company to find other solutions for coping with peak demand. The transport flexibility is also limited by a lack of transport alternatives because shipping large quantities of fuel and heating oil by truck is financially unattractive. Using other rail carriers is not an option in the case of this particular company.

TABLE 5 Characteristics of rail transport planning of a large mineral oil company in Switzerland.

Sub-category	*Feature*	*Value*			
Transport Network Structure	Number of origins	> 15	6 – 15	2 – 5	1
	Number of destinations	> 15	6 – 15	2 – 5	1
	Percentage of total transport volumes on the 20% most important relations	< 50%	50% – 60%	60% – 70%	> 70%
	Network extent	international / long-distance		domestic / short-distance	
Transport Responsibility	Number of railways involved	several		one	
	Provider of shipping-paid deliveries	yes		no	
	User of shipping-paid deliveries	no	yes, partly		yes
	Entity responsible for releasing products being shipped	≠ freight payer		= freight payer	
Transport Origin	Quantitative flexibility of production capacity at origin	flexibel in terms of time	hardly flexible in terms of time		not flexible in terms of time
	Inventory philosophy at origin	high inventory	medium inventory		minimum inventory (just-in-time)
	Entity in charge of origin site	≠ entity placing shipment order		= entity placing shipment order	
	Use of rail siding	exclusive		shared	
Transport Destination	Inventory philosophy at destination	high inventory	medium inventory		minimum inventory (just-in-time)
	Entity in charge of destination site	≠ entity placing shipment order		= entity placing shipment order	
	Use of rail siding	exclusive		shared	
Freight Customer Service Characteristics	Shipment lot size	block trains		freight wagons	
	Delivery date flexibility	± 1 week or more	± 1 day		not flexible
Sales / Procurement Plan	Time horizon	< 1 week	≥ 1 week		≥ 1 month
	Level of detail	month	week		day
	Forecast technique	intuitive[1]	mathematical[2]		none (firm orders)
Transport Plan	Time horizon	< 1 week	≥ 1 week		≥ 1 month
	Level of detail	month	week		day
	Revision cycle	daily	event-driven	weekly	no revision
Transport Flexibility	Availability of transport alternatives at short notice	yes		no	
	Latest possible time for placing transport order	≤ 1 day prior to shipping	≤ 1 week prior to shipping		> 1 week prior to shipping
	Transport vehicle ownvership	ad-hoc leasing		proprietary possession / long-term leasing	
	Non-transport measures for adressing demand deviations	none	few		many

[1] *heating oil*
[2] *fuel*

Third, the company has numerous non-transport related measures for coping with demand deviations. This is explainable by statutory stockpiling requirements for mineral oil companies and the fact that mineral oil companies are basically trading identical products.

The quantity of statutory stockpiling for a mineral oil company is determined by law, but regulations allow bookkeeping transfers of statutory stocks between approved distribution depots within Switzerland.

This possibility allows the company's transport-planning unit to address a shortage in one distribution depot by reducing that depot's compulsory stock and increasing the compulsory stock by the same amount in another depot. The fact that most distribution depots are operated as joint ventures and managed by the transport planning unit opens up a range of further possibilities. For instance, it enables transactions with competitors from the same distribution depot. This can be transfers of stocks or the short-term leasing of additional storage capacities to avoid an imminent overflow.

An additional advantage is that distribution depots generally store both heating oil and fuel. Hence, the analysed company may operate block trains as initially planned but with other goods (e.g. heating oil instead of fuel). It is also partly possible for the company to handle customer cancellations of carriage paid block train deliveries without changing transport plans. If these customers are using the same joint-venture distribution depots as the analysed company, the already planned block trains can be used to supply the company's own storage tanks. In both cases, there is no change in transport plans necessary.

The above results are especially interesting when they are compared with other companies. This company serves as benchmark for a high forecast quality in the mineral oil sector of Switzerland. As the decisive underlying conditions have been identified, forecasts of a similar quality can be demanded from other companies with comparable characteristics.

5. DISCUSSION

The morphological analysis scheme presented in this paper provides a structured framework for analysing the quality of rail transport forecasting from freight shipping companies. The framework can help explain forecast and shipment order quality. It also helps analysts understand inconsistencies between expected and actually provided forecast and order information.

The morphological scheme's main benefit is the possibility to compare rail transport planning from different freight shippers using a uniform methodology. This enables railways to determine benchmark values for achievable forecast periods and accuracy rates for freight shipping companies. These benchmarks can then be used to identify companies operating with similar transport planning conditions, and railways can request forecasts from companies which have a good potential for providing accurate forecasts.

Finally, the benchmark values can be used by other companies to help improve rail freight forecasting in their own companies. Freight railways have an immediate interest on these improvements and should therefore push such activities actively.

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