

DISS ETH NO. 20610

**PRODUCTIVITY IMPROVEMENTS FOR FREIGHT  
RAILWAYS THROUGH COLLABORATIVE  
TRANSPORT PLANNING**

A dissertation submitted to  
ETH ZURICH

for the degree of  
Doctor of Sciences

presented by  
STEPHAN MARTIN MOLL  
Dipl. Ing. ETH  
born February 5, 1979  
citizen of Dulliken (Solothurn)

accepted on the recommendation of  
Prof. Dr. Ulrich Weidmann, examiner  
Prof. Dr. Wolfgang Stölzle, co-examiner

2012



# Abstract

---

Freight transportation is a dynamic and competitive market with high requirements on reliability and flexibility. Goods flow oriented logistic concepts with minimized stocks and shipment lot sizes increasingly lead to immediate and little buffered fluctuations in transport demand. As a consequence, offering flexible transport solutions has become a key requirement for logistic service providers. This situation is particular challenging for freight railways, as they have to cope with numerous infrastructural and regulatory constraints. Freight railways are thus confronted with a difficult balancing act between providing flexible transport solutions and operating at high productivity – in addition to strong pricing pressure.

In this regard, a promising but still rarely applied approach is the anticipation of future transport demand and the targeted exertion of influence through operational planning collaborations between shippers and freight railways. Prompt exchanges of information as well as joint operational planning could help make the use of transport resources more productive, without limiting the flexibility of shippers. The implementation of such collaborations has to consider individual capabilities of shippers as well as actual needs of freight railways. This requires an in-depth understanding of operational planning processes and determinants on both shipper and freight railway side. These considerations have led to the following research question:

What is the potential of operational collaborations between shippers and freight railways and how do they affect freight rail productivity?

This implies the following detailed questions: Which operational processes are relevant for productivity at freight railways and would profit from collaborations with shippers? What information is needed at what time and in which quality? How is transport planning performed on shippers' side? What information is available at what time and in which quality? What affects planning quality? Which forms of operational collaborations qualify to be implemented between shippers and freight railways and what is the effect on freight rail productivity?

These questions were empirically approached on the example of Switzerland with numerous face-to-face interviews at a Swiss freight railway and their customers. These qualitative findings were complemented with quantitative analyses on short-term shipment forecasts and operated trains, supporting the interpretation and validation of

interview results. The use of process modelling methods, morphological analyses, and influence matrices helped structure and interpret gathered information systematically.

Analyses on the freight railway side indeed show a lack of operational collaborations with customers. They are generally limited to the shipment ordering process and subsequent modifications. This hampers an efficient and effective planning. Operational processes that would benefit most from enhanced collaborations are short-term timetable planning and the leasing of locomotives and train drivers. In many cases, the exchange of (forecast) information already suffices to help responsible planners improve freight rail productivity. The study also revealed that needed shipper information strongly depends on the intended use at the freight railway and considerably differs in terms of accuracy, time horizon and level of detail.

Analyses on shippers' side focused on the three commodities mineral oil, gravel, and steel scrap. In the mineral oil sector, operational rail transport planning is typically divided in a rolling monthly planning process and an event-driven short-term planning process. Despite of differing prerequisites at shippers, empirical results imply that accurate transport forecasts are generally feasible within a time horizon of 2-3 weeks. In the gravel sector, operational rail transport planning is done on a weekly basis with a planning horizon of one week. Shippers thus hardly know more than the freight railway. A number of factors make the implementation of operational collaborations indeed highly difficult in this sector. In the steel scrap sector, operational transport planning is basically a day-to-day activity with a time horizon of few days only. Numerous characteristics suggest that accurate transport forecasts as well as balanced daily shipments are possible. However, a transfer of transport planning competences from suppliers to one single actor of the supply chain network would be necessary for implementing effective collaborations.

The study identified and assessed twelve potential forms of collaborative approaches. They notably improve the efficiency of locomotives and train drivers and the effectiveness of single wagonload trains. Two particularly promising collaborative approaches are the use of shipment forecasts for joint levelling traffic peaks and for leasing locomotives at traffic peaks. Further promising collaborative approaches are found in the fields of capacity planning of single wagonload trains, freight wagon booking, and demand-oriented availability planning of locomotives.

Overall, the study could show that there are several implementable forms of operational collaborations between shippers and freight railways in Switzerland, which help increase freight rail productivity. However, the potential is not equally given for all transport sectors, due to heterogenic transport planning processes and determinants. This makes sector-specific forms of collaborations necessary. Eventually, conducted interviews have also disclosed the significant cultural influence for implementing new collaborative approaches. In Switzerland, for instance, collaborative approaches are favoured by a distinct culture of dialogue and compromise.

# Zusammenfassung

---

Der Güterverkehr ist ein dynamischer und wettbewerbsintensiver Markt mit hohen Anforderungen an Zuverlässigkeit und Flexibilität. Güterflussorientierte Logistikkonzepte mit minimierten Lagerbeständen und Sendungsgrößen führen dabei zunehmend zu unmittelbaren und wenig gepufferten Schwankungen in der Transportnachfrage. Die Fähigkeit zu flexiblen Transportlösungen ist damit für Logistikdienstleister ein entscheidender Erfolgsfaktor geworden. Für Güterbahnen stellt dies eine besondere Herausforderung dar, da sie durch zahlreiche infrastrukturelle und regulatorische Rahmenbedingungen eingeschränkt sind. Güterbahnen befinden sich somit auf einer schwierigen Gratwanderung zwischen flexiblen Transportlösungen und einer genügend hohen Produktivität – und dies im Umfeld eines allgemein hohen Wettbewerbsdrucks.

In dieser Beziehung stellt die Antizipation von zukünftigen Verkehren und deren Einflussnahme durch operative Kooperationen zwischen der Güterbahn und ihren Kunden ein vielversprechender, aber noch wenig genutzter Ansatz dar. Der zeitnahe Austausch von Informationen sowie gemeinsame Planungen erlauben den produktiveren Einsatz von Transportressourcen ohne die Flexibilität der Kunden einzuschränken. Dabei sind jedoch sowohl die Möglichkeiten auf der Kundenseite, als auch die effektiven Bedürfnisse der Güterbahnen zu berücksichtigen. Dies bedingt ein umfassendes Verständnis der operativen Transportplanungsprozesse und Determinanten auf Seite der Güterbahn und der Kunden. Diese Überlegungen haben zur folgenden Forschungsfrage geführt:

Was ist das Potential von operativen Kooperationen zwischen Güterbahnen und deren Kunden und wie beeinflussen sie die Produktivität im Schienengüterverkehr?

Daraus wurde eine Reihe von detaillierten Fragen abgeleitet: Welche operativen Prozesse sind bei Güterbahnen für die Produktivität relevant und würden von Kooperationen mit Kunden profitieren? Welche Informationen werden wann und in welcher Qualität gebraucht? Wie wird die Transportplanung bei den Kunden durchgeführt? Welche Informationen sind wann und in welcher Qualität verfügbar? Was beeinflusst die Planung? Und schliesslich: Welche Formen von operativen Kooperationen sind für eine Implementierung geeignet und wie wirken sich diese auf die Produktivität aus?

Diese Fragen wurden am Beispiel der Schweiz mit zahlreichen persönlichen Interviews bei einer Schweizerischen Güterbahn und ihren Kunden empirisch angegangen. Diese qualitativen Resultate wurden ergänzt durch quantitative Auswertungen von kurzfristigen Transportvorhersagen und effektiven Verkehren. Des Weiteren wurden in der Studie

Prozessmodellierungsmethoden, morphologische Tabellen und Wirkungsmatrizen für eine systematische Herangehensweise angewendet.

Die Analysen auf Seite der Güterbahn zeigen, dass die operative Zusammenarbeit mit Kunden noch wenig ausgeprägt ist und eine effiziente und effektive Planung beeinträchtigt. Sie ist im Wesentlichen auf die Transportbestellung und allfälligen nachträglichen Änderungen beschränkt. Die kurzfristige Fahrplanplanung und die Miete von Lokomotiven und Lokführern würden von einer verstärkten Zusammenarbeit besonders profitieren. In vielen Fällen erlaubt der Austausch von Vorhersagen bereits eine Produktivitätsverbesserung. Die benötigten Informationen hängen allerdings stark vom Verwendungszweck ab und unterscheiden sich insbesondere im Bezug auf die erforderliche Genauigkeit, dem Zeithorizont und dem Detaillierungsgrad.

Die Analysen auf der Kundenseite konzentrierten sich auf die drei Transportsektoren Mineralöl, Kies und Schrott. Im Mineralölsektor ist die operative Transportplanung typischerweise in eine monatliche und eine ereignisorientierte Planung unterteilt. Trotz unterschiedlicher Voraussetzungen bei den Kunden deuten die empirischen Resultate auf generell belastbare Transportvorhersagen mit einem Zeithorizont von 2-3 Wochen hin. Im Kiessektor erfolgt die Transportplanung wöchentlich und mit einem Planungshorizont von einer Woche. Die Kunden wissen demnach kaum mehr als die Güterbahn. Insgesamt zeigt sich die Situation in diesem Transportsektor äusserst ungünstig für die Einführung von operativen Kooperationen. Im Schrottsektor erfolgt die Transportplanung von Tag zu Tag mit einem Planungshorizont von wenigen Tagen. Verschiedene Faktoren sprechen für genaue Vorhersagen und gleichmässige Verkehre auf der Schiene. Um daraus aber wirkungsvolle Kooperationen aufzubauen, müssten gewisse Planungskompetenzen von den Zulieferern an einen zentralen Akteur der Transportkette abgetreten werden.

Die Studie identifizierte und beurteilte zwölf potentielle Formen von operativen Kooperationen. Diese erhöhen primär die Effizienz von Lokomotiven und Lokführern sowie die Effektivität von Zügen im Einzelwagenladungsverkehr. Zwei besonders vielversprechende Ansätze stellen das gemeinsame Brechen von Verkehrsspitzen sowie die proaktive Miete von Transportressourcen auf Basis von übermittelten Transportprognosen dar. Weitere Potentiale für Kooperationen finden sich im Bereich der Kapazitätsplanung von Zügen im Einzelwagenladungsverkehr, der Buchung von Güterwagen und der bedarfsorientierten Verfügbarkeitsplanung von Lokomotiven.

Insgesamt konnte die Studie mehrere Formen von implementierbaren operativen Kooperationen zwischen Güterbahnen und ihren Kunden identifizieren, welche die Produktivität im Schienengüterverkehr verbessern helfen. Aufgrund heterogener Transportplanungsprozesse und Determinanten ist das Potential jedoch nicht in jeden Transportsektor gleichermassen gegeben. Dies erfordert branchenspezifische Zusammenarbeitsformen. Schliesslich zeigte sich in den Interviews auch der kulturelle Einfluss bei der Einführung von neuen Zusammenarbeitsformen. Diese wird in der Schweiz durch eine ausgeprägte Dialog- und Kompromisskultur begünstigt.

# Acknowledgements

---

This dissertation was realised during my time as a research assistant in the Transport Systems group at the Institute for Transport Planning and Systems. It would not have been feasible without the support of many people, to whom I would like to express my gratitude.

First of all, I want to thank my supervisor Prof. Dr. Ulrich Weidmann, who made this dissertation actually possible. I am very thankful for his concise methodological and practical advices as well as his encouraging support. I am also very thankful to have had the opportunity to work in his group and gain practical experience through the participation in several interesting research projects. Many thanks also go to my co-supervisor, Prof. Dr. Wolfgang Stölzle, for his constructive inputs and the willingness to referee my dissertation.

Special thanks go to the numerous people at SBB Cargo, who patiently answered my questions and assessed the results from an industrial point of view. In particular, I want to thank Daniel Müller, Sigfried Flury, and Roland Rieder for the fruitful discussions and the willingness to provide me with any support I needed. Many thanks also go to my interview partners at the shipping companies for the profound insights about their respective transport sectors. I am very grateful for their openness towards my questions and the valuable inputs for my dissertation.

Furthermore, I want to thank all my colleagues at IVT, in particular Dr. Dirk Bruckmann, Emanuel Barth, Bernd Bopp, Robert Dorbritz, Patrick Frank, Uwe Kirsch, Marcus Rieder, and Jost Wichser. It was an unforgettable time and I really enjoyed being part of this group.

Eventually, I want to thank my family, my friends, and in particular my wife Lilian. You gave me the motivation, strength, and confidence to successfully finish this dissertation and I am deeply grateful for the love and friendship through all these years.

# Contents

<b>1</b>	<b>INTRODUCTION</b> .....	<b>1</b>
1.1	MOTIVATION .....	1
1.2	GOAL OF RESEARCH .....	2
1.3	OUTLINE AND SCOPE OF RESEARCH .....	3
<b>2</b>	<b>INTRODUCTION TO TRANSPORT PLANNING AND PRODUCTIVITY IN RAIL FREIGHT</b>	<b>4</b>
2.1	INTRODUCTION TO RAIL FREIGHT .....	4
2.1.1	Rail Freight Performance .....	4
2.1.2	Rail Freight Services .....	5
2.1.3	Competitive Situation .....	7
2.2	INTRODUCTION TO TRANSPORT AND COLLABORATIVE PLANNING.....	7
2.2.1	Basic Aspects of Planning .....	7
2.2.2	Transport Planning .....	9
2.2.3	Collaborative Planning .....	13
2.3	CHARACTERISTICS OF PRODUCTIVITY .....	16
2.3.1	General Term and Function .....	16
2.3.2	Types of Productivity Measurement .....	17
2.3.3	Productivity in Rail Freight .....	17
<b>3</b>	<b>RESEARCH HYPOTHESES</b> .....	<b>19</b>
3.1	NEED FOR OPERATIONAL COLLABORATIONS .....	19
3.2	EXISTING CAPABILITIES AT SHIPPERS.....	20
3.3	FEASIBILITY OF IMPLEMENTATION .....	20
<b>4</b>	<b>RESEARCH METHODOLOGY</b> .....	<b>22</b>
4.1	METHODOLOGICAL CONCEPT .....	22
4.2	APPLIED METHODS .....	24
4.2.1	Modelling of Planning Procedures .....	24
4.2.2	Impact Analyses on Planning and Productivity.....	26
4.2.3	Gathering of Empirical Information .....	29
<b>5</b>	<b>IDENTIFICATION OF RELEVANT FREIGHT RAIL PROCESSES FOR PRODUCTIVITY</b>	<b>32</b>
5.1	OPERATIONAL PROCESSES AT FREIGHT RAILWAYS.....	32
5.2	REQUIREMENTS FOR HIGH RAIL FREIGHT PRODUCTIVITY .....	35
5.2.1	Approach .....	35
5.2.2	Discussion.....	36
5.2.3	Summary.....	39
5.3	EVALUATION OF OPERATIONAL PROCESSES.....	40
5.3.1	Approach .....	40
5.3.2	Discussion.....	41
5.3.3	Summary.....	46
<b>6</b>	<b>ANALYSIS OF RELEVANT FREIGHT RAIL PROCESSES FOR PRODUCTIVITY</b> .....	<b>48</b>
6.1	INTRODUCTION .....	48
6.2	SHORT-TERM TIMETABLE PLANNING (BLOCK TRAINS).....	48
6.2.1	Process .....	48
6.2.2	Discussion.....	51
6.2.3	Collaborative Approaches .....	52
6.3	SHORT-TERM TIMETABLE PLANNING (SINGLE WAGONLOAD) .....	55



6.3.1	Process .....	55
6.3.2	Discussion.....	56
6.3.3	Collaborative Approaches .....	56
6.4	LEASING OF ROLLING STOCK AND PERSONNEL .....	57
6.4.1	Process .....	57
6.4.2	Discussion.....	59
6.4.3	Collaborative Approaches .....	60
6.5	PREVENTIVE MAINTENANCE PLANNING (LOCOMOTIVES) .....	62
6.5.1	Process .....	62
6.5.2	Discussion.....	63
6.5.3	Collaborative Approaches .....	64
6.6	PLANNING OF VACATION, OVERTIME, AND TOIL.....	64
6.6.1	Process .....	64
6.6.2	Discussion.....	65
6.6.3	Collaborative Approaches .....	66
6.7	DISTRIBUTION PLANNING OF EMPTY WAGONS.....	66
6.7.1	Process .....	66
6.7.2	Discussion.....	68
6.7.3	Collaborative Approaches .....	69
6.8	SUMMARY.....	71
<b>7</b>	<b>FRAMEWORK FOR ANALYSING SHIPPERS' RAIL TRANSPORT PLANNING.....</b>	<b>77</b>
7.1	INTRODUCTION .....	77
7.2	TRANSPORT LOGISTIC ORGANISATION .....	78
7.2.1	Transport Network Structure .....	78
7.2.2	Transport Responsibility.....	79
7.2.3	Characteristics at Transport Origin and Destination .....	80
7.3	SALES/PROCUREMENT PLANNING.....	82
7.3.1	Shipper's Service Characteristics .....	82
7.3.2	Sales/Procurement Plan .....	82
7.4	TRANSPORT PLANNING .....	83
7.4.1	Transport Plan.....	83
7.4.2	Transport Flexibility .....	84
7.4.3	Provided Information to Railway .....	85
7.5	SUMMARY.....	87
<b>8</b>	<b>ANALYSIS OF SHIPPERS' RAIL TRANSPORT PLANNING .....</b>	<b>88</b>
8.1	SELECTION OF TRANSPORT SECTORS.....	88
8.2	MINERAL OIL .....	92
8.2.1	Introduction.....	92
8.2.2	Empirical Results.....	94
8.2.3	Evaluation .....	104
8.3	GRAVEL .....	108
8.3.1	Introduction.....	108
8.3.2	Empirical Results.....	110
8.3.3	Evaluation .....	116
8.4	STEEL.....	119
8.4.1	Introduction.....	119
8.4.2	Empirical Results.....	121
8.4.3	Evaluation .....	127
8.5	SUMMARY.....	130

<b>9</b>	<b>POTENTIAL OF COLLABORATIVE APPROACHES.....</b>	<b>132</b>
9.1	SYNTHESIS OF PRESENT FINDINGS.....	132
9.2	APPROACH 1 – USING SHIPMENT FORECASTS FOR JOINT LEVELLING TRAFFIC PEAKS.....	135
9.2.1	Motivation for Participants.....	135
9.2.2	Process Design.....	136
9.2.3	Quantification of Benefit.....	138
9.3	APPROACH 2 – JOINT PLANNING OF FEEDER RELATIONS WITH DOMINANT SHIPPERS.....	142
9.3.1	Motivation for Participants.....	142
9.3.2	Process Design.....	143
9.3.3	Quantification of Benefit.....	145
9.4	APPROACH 3 – USING SHIPMENT FORECASTS FOR LEASING LOCOMOTIVES AT TRAFFIC PEAKS ...	148
9.4.1	Motivation for Participants.....	148
9.4.2	Process Design.....	149
9.4.3	Quantification of Benefit.....	151
9.5	SUMMARY AND RECOMMENDATION.....	155
<b>10</b>	<b>CONCLUDING REMARKS AND PERSPECTIVES FOR FURTHER RESEARCH.....</b>	<b>158</b>
10.1	SUMMARY OF KEY RESULTS.....	158
10.2	CONCLUDING REMARKS.....	160
10.3	PERSPECTIVES FOR FURTHER RESEARCH.....	161
	<b>APPENDICES .....</b>	<b>162</b>
	APPENDIX A – DESCRIPTION AND EVALUATION OF POSSIBLE PROCESS MODELLING METHODS.....	162
	APPENDIX B – DERIVATION OF INDICATORS DESCRIBING PRODUCTIVITY AT FREIGHT RAILWAYS .....	170
	APPENDIX C – ELABORATION OF ANNUAL ROSTER FOR TRAIN DRIVERS .....	179
	APPENDIX D – ANALYSIS OF SELECTED TRANSPORT SECTORS .....	180
	APPENDIX E – INTERVIEW GUIDELINE .....	186
	APPENDIX F – BASIC DEFINITIONS .....	187
	APPENDIX G – CURRICULUM VITAE.....	188
	<b>BIBLIOGRAPHY .....</b>	<b>189</b>

# List of Tables

Table 2-1: Goods transported on rail in Switzerland.....	4
Table 2-2: Market share of freight railways in Switzerland .....	7
Table 2-3: Advantages of collaborative transport planning.....	14
Table 4-1: Classification matrix of modelling methods .....	25
Table 5-1: Process influence matrix .....	47
Table 6-1: Characteristics of required information: Features and possible values .....	72
Table 6-2: Summary of identified collaborative approaches.....	74
Table 7-1: Transport network structure: features and proposed values .....	79
Table 7-2: Transport responsibility: features and proposed values .....	79
Table 7-3: Characteristics at transport origin and destination: features and proposed values .....	80
Table 7-4: Shipper's service characteristics: features and proposed values .....	82
Table 7-5: Sales/procurement plan: features and proposed values .....	83
Table 7-6: Transport plan: features and proposed values .....	84
Table 7-7: Transport Flexibility: features and proposed values .....	84
Table 7-8: Provided Information to railways: features and proposed values .....	86
Table 8-1: Calculated indicators for important transport sectors in Switzerland.....	90
Table 8-2: Typical crude oil fractions and uses .....	92
Table 8-3: Transport network & responsibilities: results .....	96
Table 8-4: Transport origin and destination: results .....	97
Table 8-5: Sales planning: results .....	97
Table 8-6: Transport planning: results .....	101
Table 8-7: Provided planning output to freight railway: results (1/2).....	102
Table 8-8: Provided planning output to freight railway: results (2/2).....	103
Table 8-9: Differences in shippers' characteristics and provided information.....	105
Table 8-10: Forecast potential for rail transports in the mineral oil sector .....	108
Table 8-11: Classification of detrital sedimentary rocks .....	109
Table 8-12: Transport network & responsibilities: results .....	111
Table 8-13: Transport origin and destination: results .....	112
Table 8-14: Sales planning: results .....	112
Table 8-15: Transport planning: results .....	114
Table 8-16: Provided planning output to freight railway: results .....	115
Table 8-17: Reasons for missing forecasts and low order accuracies .....	117
Table 8-18: Forecast potential for rail transports in the gravel sector.....	119
Table 8-19: Transport network & responsibilities: results .....	123

Table 8-20: Transport origin and destination: results.....	124
Table 8-21: Procurement planning: results .....	125
Table 8-22: Transport planning: results .....	126
Table 8-23: Reasons for contradicting situation in the steel scrap transport sector .....	129
Table 8-24: Forecast potential for rail transports in the steel scrap sector .....	130
Table 9-1: Conditions for joint planning feeder relations.....	148
Table 9-2: Sensitivity analysis of cost saving potential .....	153

# List of Figures

Figure 2-1: Main rail freight services.....	5
Figure 2-2: Main processes at freight railways .....	9
Figure 2-3: Supply chain planning matrix .....	11
Figure 2-4: Constraints influencing transport logistics .....	12
Figure 2-5: Productivity in context with other company goals.....	16
Figure 4-1: Methodological concept.....	23
Figure 4-2: Exemplary influence matrix .....	27
Figure 4-3: Exemplary scheme for morphological analyses .....	28
Figure 5-1: Operational processes at freight railways .....	32
Figure 5-2: Proposed indicators for describing productivity at freight railways .....	36
Figure 5-3: Requirements for high efficiency at freight railways .....	37
Figure 5-4: Requirements for high effectiveness at freight railways .....	38
Figure 5-5: Requirements for low unit costs and high earning power.....	39
Figure 5-6: Requirements for high productivity at freight railways.....	40
Figure 6-1: Timetabling process of weekly block train orders (1/2) .....	49
Figure 6-2: Timetabling process of weekly block train orders (2/2) .....	51
Figure 6-3: Short-term leasing of locomotives .....	58
Figure 6-4: Joint safety stock of locomotives .....	61
Figure 6-5: Process of preventive maintenance planning (locomotives) .....	63
Figure 6-6: Distribution planning of empty wagons.....	67
Figure 6-7: Value of shipper information in function of covered transport volumes at the freight railway.....	72
Figure 6-8: Summary of results and classification of collaborative approaches .....	76
Figure 7-1: Main areas with relevance to rail transport planning .....	77
Figure 8-1: Share of regular traffic in intermodal transports .....	89
Figure 8-2: Variation of weekly transport volumes intermodal transports.....	89
Figure 8-3: Price volatility of fuel and heating oil in Switzerland .....	93
Figure 8-4: Supply chain structure in the mineral oil industry .....	94
Figure 8-5: Typified monthly planning process .....	99
Figure 8-6: Typified event-driven planning process during the month.....	100
Figure 8-7: Transport strategy with partly outsourced rail transports .....	106
Figure 8-8: Typical supply chain structures in the gravel industry .....	110
Figure 8-9: Typified planning process of gravel transports on rail .....	113
Figure 8-10: Analysis of gravel shipments on rail in Switzerland.....	115

Figure 8-11: Source of volatile and unpredictable gravel demand.....	118
Figure 8-12: Monthly steel production in Switzerland .....	120
Figure 8-13: Supply chain structure in the steel industry .....	121
Figure 8-14: Analysed rail transports in the steel industry .....	122
Figure 8-15: Responsibilities in rail transports of steel scrap in Switzerland .....	124
Figure 8-16: Basic procedure of steel scrap procurement.....	125
Figure 8-17: Analysis of steel scrap shipments on rail in Switzerland .....	127
Figure 9-1: Suitability of collaborative approaches at analysed sectors .....	133
Figure 9-2: Summary of results.....	134
Figure 9-3: Design of new process - overview.....	136
Figure 9-4: Design of new process - details.....	137
Figure 9-5: Effect of applied planning principles on dimensioning of resources .....	138
Figure 9-6: Deviation of daily operated trains from annual average .....	139
Figure 9-7: Deviation of weekly operated trains from annual average.....	140
Figure 9-8: Effect of applied levelling measure .....	141
Figure 9-9: Design of new process - overview.....	144
Figure 9-10: Design of new process - details.....	144
Figure 9-11: Distribution of reducible trains on feeder relation B over the week .....	147
Figure 9-12: Design of new process - overview.....	150
Figure 9-13: Design of new process - details.....	151
Figure 9-14: Illustration of method for quantifying benefit.....	153
Figure 9-15: Break even function for leasing additional locomotives .....	154
Figure 9-16: Summary of results.....	157

# 1 Introduction

---

## 1.1 Motivation

Freight transportation is a dynamic and competitive market with high requirements on reliability and flexibility. As in all highly developed countries, the importance of bulk goods in freight traffic tends to stagnate or even decline in Switzerland, while the significance of consumer and investment goods keeps on rising. ELBERT AND GOMM (2003) have disclosed the consequences for the transport market. They identified – inter alia – a trend to smaller transportation lots and reduced lead times for transportation services. Goods flow oriented logistic concepts at shippers largely contribute to this major trend [SCHÖNSLEBEN (2004)]. They minimize inventory in stock and work-in-progress by investing in logistics, production techniques, and technology instead. This increasingly leads to immediate and little buffered fluctuations in transport demand. Being able to offer flexible transport solutions has thus become a key requirement for logistic service providers.

This situation is particular challenging for freight railways. They are confronted with a number of infrastructural and regulatory constraints, which make flexible transport planning and optimisations difficult at short-notice. Nevertheless, freight railways are compelled to offer flexible transport solutions for succeeding in the highly competitive freight transport market. This leaves freight railways with little time for creating well-adjusted timetables and duty schedules. Freight railways are thus confronted with a difficult balancing act between providing flexible transport solutions and operating at high productivity – in addition to strong pricing pressure.

In this context, freight railways basically have three options. The first option is to concentrate on transport sectors with constant and predictable transport demand. The result is a significant reduction of planning complexity and sufficient time for creating optimal duty schedules. In turn, the freight railway has to renounce on significant transport volumes. Pursuing this strategy is a fundamental company-specific decision at which academic research can little contribute. The decision largely depends on the existence of suitable transport sectors, whose shipping volumes are large enough and geographically concentrated to justify an economic operation in a long-term perspective.

The second – commonly applied – option is to integrate generated costs for flexible transport solutions in sector-specific transport rates. If that is not possible, stricter rules for placing shipment orders have to be established. This logical interdependency is increasingly difficult to enforce by freight railways without loosing significant transport

volumes to competitors. Furthermore, shippers' reaction on changed transport conditions is difficult to estimate in advance. Freight railways are thus cautious modifying them.

The third option circumvents these difficulties. The freight railway anticipates future transport demand and exerts targeted influence by means of operational planning collaborations with shippers. For budgeting purposes and evaluations of general market perspectives, close collaborations with shippers have already been established in rail freight. On the operational level however, planning collaborations is regarded as a still insufficiently applied approach. Prompt exchanges of information as well as coordinated operational transport plans could help make deployments of transport resources more productive, without limiting transport flexibility of shippers. However, implementing such collaborations are complex and multifaceted, as it has to consider capabilities of shippers as well as actual needs at the freight railway. This requires an in depth understanding of operational planning processes and determinants on both shipper and freight railway side.

## 1.2 Goal of Research

The goal of this research is to evaluate the potential of operational collaborations between shippers and freight railways with regards to productivity at freight railways. In other words, this study wants to investigate whether increased information exchanges and planning integrations are feasibly and valuable for both shippers and freight railways.

Hence the main question to be answered in this research is:

**What is the potential of operational collaborations between shippers and freight railways and how do they affect freight rail productivity?**

This implies the following detailed questions:

1. Which operational processes are relevant for productivity at freight railways and would profit from collaborations with shippers? What information is needed at what time and in which quality?
2. How is transport planning performed on shippers' side? What information is available at what time and in which quality? What affects planning quality?
3. Which forms of operational collaborations qualify to be implemented between shippers and freight railways and what is the effect on freight rail productivity?



## 1.3 Outline and Scope of Research

The aforementioned research questions lead to the following basic structure of this study. Chapter 2 provides a general introduction to the main topics of this research. This comprises an overview of the rail freight market and services, characteristics of transport and collaborative planning, and basic aspects of productivity. The introduction is followed by chapter 3, which includes the research hypotheses of this study and the discussion of current gaps in research. The methodological concept is subsequently presented in chapter 4. Chapters 5 and 6 are dedicated to analyses on the freight railway side, while 7 and 8 are the respective chapters on shippers' side. The results of these chapters are brought together in chapter 9 and discussed in more detail by means of several case studies. The study closes with the summary of key results and perspectives for further research in chapter 10.

SBB Cargo – the leading Swiss Freight Railway – could be gained as industrial partner for this research. This collaboration not only provided valuable insights in rail transport planning of a freight railway but also helped establish fruitful contacts to major shippers in Switzerland. This high information availability consequently led to the decision to focus the empirical parts of this research on Switzerland. The methodological approach of this study, however, is generally applicable and not bound to a specific country.

# 2 Introduction to Transport Planning and Productivity in Rail Freight

## 2.1 Introduction to Rail Freight

### 2.1.1 Rail Freight Performance

According to EU regulations, the standard goods classification for transport statistics (NST/R) is used to classify transported goods in rail transport statistics<sup>1</sup>. NST/R differentiates 20 divisions of commodities, which are further subdivided in 81 detailed groups<sup>2</sup>. Table 2-1 shows the significance of conveyed goods in Swiss rail freight performance.

**Table 2-1: Goods transported on rail in Switzerland**

NST/R divisions	Description	rail freight performance in Switzerland (2010) <sup>1</sup>	
		millions net tons-km	%
15 - 20	other goods	6,739	62.7%
7	coke and refined petroleum products	951	8.8%
3	mining and quarrying products	623	5.8%
10	basic metals and fabricated metal products	569	5.3%
8 - 9	chemical and non-metallic mineral products	528	4.9%
4 - 6	consumer goods for immediate consumption	499	4.6%
1	products of agriculture and forestry	374	3.5%
11 - 13	machinery and equipment; durable consumer goods	233	2.2%
14	secondary raw materials and wastes	216	2.0%
2	coal, crude petroleum and natural gas	19	0.2%
		<b>10,750</b>	<b>100.0%</b>

<sup>1</sup> railways with less than 500 mio net tons-km/a not considered

Source: Swiss Federal Statistical Office

The nature of conveyed goods is evidently unknown for the large majority of rail transports in Switzerland. This is because the content of containers, swap-bodies, and semitrailers on intermodal trains is not statistically recorded. Such intermodal trains are dominating rail traffic on Swiss transit corridors via Gotthard and Simplon. Beside intermodal transports, bulk commodities like refined petroleum, metals, or quarrying

<sup>1</sup> Commission Regulation (EC) No 1304/2007 of 7 November 2007

<sup>2</sup> For details please refer to STATISTISCHES BUNDESAMT (2008)

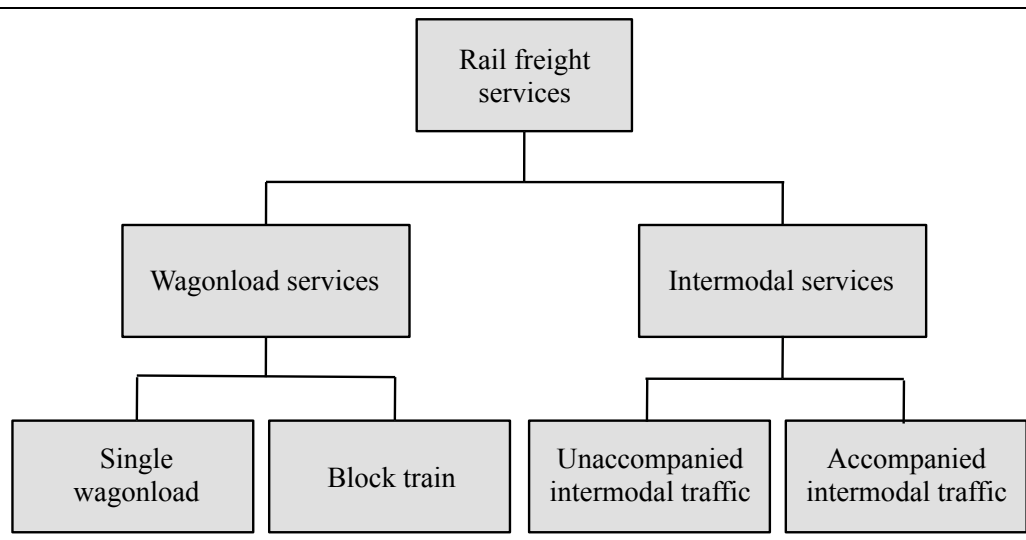
products generate nearly 30% of Swiss rail freight performance<sup>3</sup>. The shipping of consumer goods eventually represents a small part of Swiss rail freight performance only with a share of 6.8%<sup>4</sup>.

## 2.1.2 Rail Freight Services

### 2.1.2.1 Overview

ARNOLD ET AL. (2008) groups rail freight services in wagonload services and intermodal services (Figure 2-1). In wagonload services, the goods are conveyed from siding to siding by rail. They are further subclassified in single wagonload and block train services. Intermodal services involve at least two different transport modes, in which rail is typically responsible for the main haul. Intermodal services are divided in accompanied and unaccompanied intermodal services. Part-load services are occasionally mentioned as a third rail freight service. However, most rail freight railways have outsourced or suspended this service for many years<sup>5</sup>.

**Figure 2-1: Main rail freight services**



Source: Author / based on ARNOLD ET AL. (2008)

### 2.1.2.2 Single Wagonload Service

In single wagonload service, single wagons or small wagon groups are transported by rail from siding to siding or loading platform [WICHSER (2010)]. A shipper will choose this service when he wants to dispatch one or several wagons at the time but does not have enough quantity to fill a whole train.

<sup>3</sup> NST/R divisions 1, 2, 3, 7, 8, 9, 10 and 14

<sup>4</sup> NST/R divisions 4, 5, 6, 11, 12, and 13

<sup>5</sup> e.g. Deutsche Bahn in 1997; SBB in 1996

Logistically the single wagonload system is comparable with a hub and spoke system, in which all goods are brought into a central point (hub) for sorting and are distributed out from the centre in different directions<sup>6</sup>.

The single wagonload service is a very flexible system for shippers. Basically they can choose how many wagons they want to dispatch from one day to the other. As the routes are fixed in advance, the shipper can add wagons to a train as soon and wherever he needs to. The main challenge for freight railways is to ensure sufficiently high train utilisation rates to cover the large fixed costs for operating the single wagonload network.

In Switzerland, SBB Cargo is the only freight railway offering this service. It currently operates a single wagonload network of 323 service points in Switzerland<sup>7</sup>. Shipment orders must be submitted no later than 90 minutes prior to the agreed collection time<sup>8</sup>. For national shipments, a one-day transit time is assured with delivery on the following weekday.

### **2.1.2.3 Block Train Service**

Block trains (also referred to as unit trains) consist of wagons with goods of one customer, and are shipped from the same origin to the same destination, without being split up or stored en route [UIC (2012)]. Typical commodities for block train services are refined petroleum, steel, or quarrying products. Customers choose block train services when they are able to fill up a whole train. Block trains are often attractive in terms of price and more quickly than single wagonload services. The disadvantage for customers is that they take the business risk for not being able to fill purchased block trains.

Complexity and investment costs for operating block trains are much lower than for single wagonload traffic. It is therefore not surprising that the liberalisation of the European rail freight market has primarily led to vivid competition in the field of block train services. Freight railways offer different levels of flexibility for block trains services<sup>9</sup>. Customers with regular transports order their shipments in monthly schedules, in which all departure and arrival times are planned in advance. For shipments requiring more flexibility, there are services offering trains on the basis of weekly schedules.

### **2.1.2.4 Intermodal Service**

Intermodal transport is “the movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes” [UN/ECE 2001]. This requires standardised freight carrying units, such as containers, swap bodies, or semi-trailers.

---

<sup>6</sup> For details please refer to UIC (2012) or BERNDT (2001)

<sup>7</sup> <http://www.sbbcargo.com/de/angebot/netze/grundnetz-schweiz.html>

<sup>8</sup> [http://www.sbbcargo.com/de/angebot/transportleistungen/einzelwagen\\_wagengruppen.html](http://www.sbbcargo.com/de/angebot/transportleistungen/einzelwagen_wagengruppen.html)

<sup>9</sup> For specific offers please refer to <http://www.sbbcargo.com> or <http://www.rail.dbschenker.de/>

There are two types of intermodal transport: Accompanied transport and unaccompanied transport. The difference is that in unaccompanied intermodal transports, only the freight carrying units are moved from one mode to the other, while in accompanied intermodal transports the head truck and driver is conveyed as well. In Switzerland, intermodal transports are generally a combination of rail and road. The collection and distribution of goods from/to customers is usually done by road, while rail is used for the main haul between large terminals. In these terminals the freight carrying units are transferred from one transport mode to the other. Intermodal trains between terminals are regularly scheduled, allowing forwarding agents and shippers to organise the associated pre- and final carriage by truck.

### 2.1.3 Competitive Situation

Three freight railways dominate the Swiss rail transit corridors via Gotthard and Simplon (Table 2-2). SBB Cargo is still the leading freight railway with a market share of 48%, closely followed by BLS Cargo, the second Swiss freight railway. The market share of the third freight railway – Crossrail – is significantly lower with 11%. The competitive situation is clearly different when it comes to domestic traffic. SBB Cargo is still highly dominating this market segment with a share of nearly 90%. This is largely due to the single wagonload traffic, which is exclusively operated by SBB Cargo. Other competing freight railways in domestic traffic concentrate on block train services for selected transport relations.

**Table 2-2: Market share of freight railways in Switzerland**

	transit traffic <sup>1</sup> <i>(via Gotthard/Simplon)</i>	domestic traffic <sup>2</sup>
SBB Cargo	47.6%	89%
BLS Cargo	40.3%	
CR Crossrail	10.5%	
others	1.6%	

Sources: <sup>1</sup> UVEK (2011) net tons-km in 2010; <sup>2</sup> PERRIN (2011)

## 2.2 Introduction to Transport and Collaborative Planning

### 2.2.1 Basic Aspects of Planning

Numerous decisions have to be made and coordinated within a company every day. Their significance differs, however. The more important a question is, the better it has to be prepared. This preparation is basically the task of planning [FLEISCHMANN ET AL. (2008)]. It supports decision-making by identifying and assessing alternatives of future activities. There are numerous definitions of planning in literature. This study will use the definition of BEA ET AL. (2001), who describe planning as an “information processing, well-

structured process to develop a concept, which proactively defines measures to achieve [predefined] goals”.

Planning follows a well-structured procedure to ensure high quality outputs. In this context, DOMSCHKE AND SCHOLL (2005) propose following planning phases:

- recognition and analysis of a (decision) problem
- definition of objectives
- forecasting of future developments
- identification and evaluation of feasible alternatives
- selection of best solution

Decision problems in planning often concern complex systems, for which it is neither feasibly nor reasonable to respect every detail. One of the main challenges in planning is to depict reality as simple as possible without ignoring serious aspects. Overall, there is a large number of available methods for supporting the different planning phases. Important examples are descriptive modelling methods, forecasting techniques, or mathematical optimisations tools<sup>10</sup>.

The validity of a plan always refers to a predefined planning horizon and level of detail. Accordingly, FLEISCHMANN ET AL. (2008) distinguishes between long-term (strategic), mid-term (tactical), and short-term (operational) planning:

*Long-term (strategic) planning:* On this level, strategic decisions are made to determine the prerequisites for the future development of a company. These decisions of general principle concern the company’s fundamental structure and business focus with a planning horizon of several years.

*Mid-term (tactical) planning:* The principle task of mid-term planning is the translation of strategic decisions into specific concepts and projects. Tactical planning is also responsible for estimating rough quantities of demand or needed production resources. The planning horizon typically ranges up to 24 months, which enables the consideration of seasonal development.

*Short-term (operational) planning:* This planning level specifies all activities for operational execution. It thus represents the highest degree of detail and accuracy in planning. The planning horizon typically ranges between days and few months. Superior planning levels largely determine short-term planning. Nevertheless, short-term planning has a significant influence on strategic company issues such as lead-times, delays, or the quality of customer service.

One of the greatest difficulties of planning is dealing with uncertainty. In freight transports, this notably concerns the knowledge about future shipping volumes on specific dates and transport relations. In this regard, planning generally has to rely on past data or experience, which unavoidably leads to forecast errors. Holding sufficient safety stocks

---

<sup>10</sup> For details please refer to DOMSCHKE AND SCHOLL (2005)

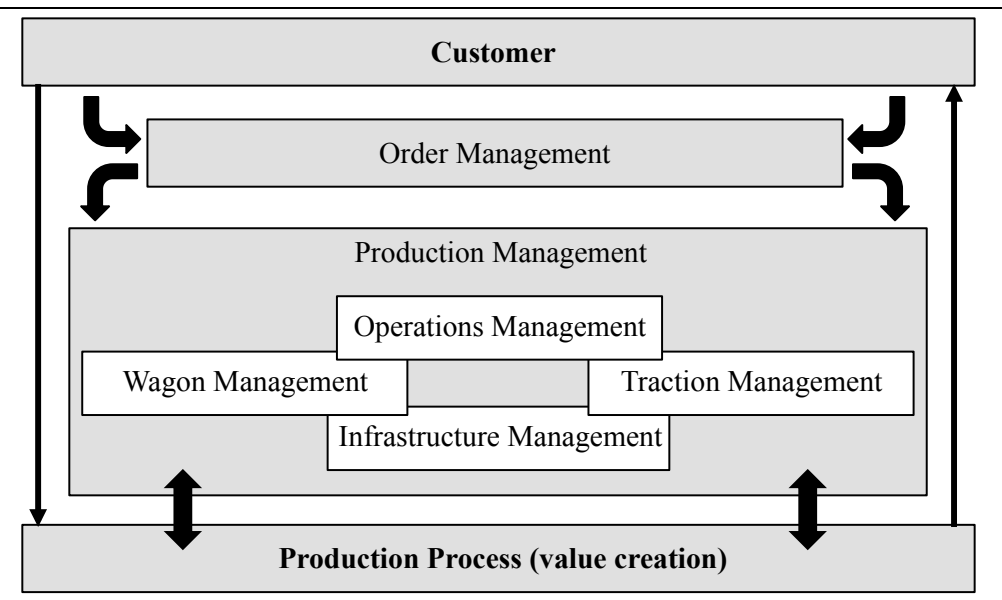
can buffer forecast errors to a certain extent. Often though, the discrepancy becomes too large and initial plans have to be revised. FLEISCHMANN ET AL. (2008) distinguishes two main approaches for that. *Planning with a rolling time horizon* pursues a plan-control-revision interaction. In this approach, the planning horizon (e.g. month) is divided into a number of periods (e.g. weeks). After the end of each period, the initial plan is revised and complemented with the next following planning period. The second approach is known as *event-driven planning*. Planning revisions are not done at regular intervals but only in case of important events, such as unexpected sales or production breakdowns. This approach is notably suited for highly dynamic environments with little regularity. It requires that all necessary planning data are updated continuously.

## 2.2.2 Transport Planning

### 2.2.2.1 Freight Railways

Freight railways create added value for customers through a reliable shipping of goods from one place to another. This requires diverse planning processes, which are fundamental for an efficient and effective operation. Overall, there are only few and scattered literature sources, which describe these planning processes specifically. The most comprehensive overview provides BERNDT (2001), which will be used as basis for a literature-based description of transport planning at freight railways (Figure 2-2).

**Figure 2-2: Main processes at freight railways**



Source: BERNDT (2001)

*Order management* represents the primary interface between customers (shippers) and freight railway. In the sense of BERNDT (2001), the main tasks of order management comprise the acquisition of orders, the monitoring of their production and the subsequent billing. As transport services are not storable, the availability of needed capacities has to

be verified first before accepting a transport request. This requires a close coordination with production management.

*Production Management* subsumes all precursor activities, which are necessary for the physical movement of goods in the production process. In this context, BERNDT (2001) distinguishes four major fields of tasks:

*Operations management* is responsible for the overall planning and controlling of the production process. A major task within operations management represents the capacity management of freight wagons, locomotives and personnel. BENDUL (2010) points out the challenge of this task in freight transportation. Due to high fixed costs, capacity management has to ensure a high utilisation of transport capacities for economic operation. At the same time, fluctuating transport demand and the need of offering flexible transport solutions make this objective difficult to achieve. In this context capacity management basically has two options: It either adjusts capacity to demand or it actively influences demand to meet (given) capacity<sup>11</sup>.

*Wagon management* organizes the dispatching of ordered freight wagons while minimizing circulation times and empty runs. A further task of wagon management – if not delegated to operations management – is the leasing of freight wagons to ensure a high availability at minimal fixed costs. Freight railways commonly use powerful IT systems for routing their freight wagons, especially in single wagonload services. This mathematical optimization task has already been subject of several research works (e.g. WURST (2004), WEYERS (2007), BEYGANG (2008)). With regards to procedures in freight wagon management, the study of QGI (2010) provides a concise overview about the order and supply process of freight wagons in the Canadian rail transport market.

*Traction management* deploys locomotives and train drivers to specific trains. CAPRARA ET AL. (2006) defines deployment planning as “the building of work schedules for assets needed to cover a planned timetable”. This task can be divided into duty scheduling and asset rostering. During duty scheduling, a convenient set of duties is being constructed. Their length is generally no longer than one or two consecutive days. A feasible duty represents a sequence of trips, breaks, and transfers, which considers existing rules and restrictions. In the subsequent asset rostering, named individuals or specific locomotives are assigned to these duties.

*Infrastructure management* at freight railways basically comprises the elaboration of timetables and the purchase of rights for using needed rail infrastructure. These train paths are bound to specific times and sections and have to be reserved at the train path allocation body of the respective country.

---

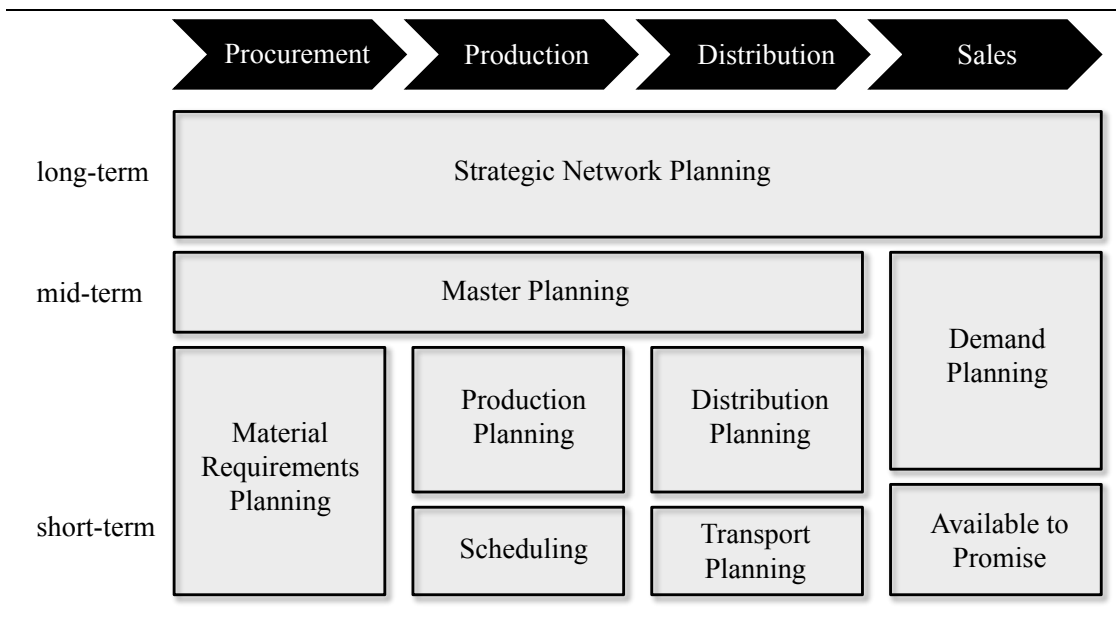
<sup>11</sup> For details please refer to BENDUL (2010), BARNES (2008), or SLACK ET AL. (2007)



### 2.2.2.2 Shippers

The *Supply Chain Planning Matrix* [ROHDE ET AL. (2000)] puts transport planning activities at shippers in context with other important business planning tasks (Figure 2-3). According to this matrix, transport planning is part of the distribution process and has a clearly operational focus<sup>12</sup>. Mid- and long-term planning is done in joint master or strategic network planning. While transport planning receives their main information from upstream distribution planning, it also has close links to production scheduling and sales for coordinating actual deliveries.

**Figure 2-3: Supply chain planning matrix**



Source: ROHDE ET AL. (2000)

FLEISCHMANN ET AL. (2008) describe typical tasks in the distribution process. An important distribution-related output of strategic network planning is the fundamental design of distribution. This includes determining the numbers, locations, and capacities of warehouses but also the question, whether transports are performed in-house or outsourced to third-party logistic providers. The main task of mid-term distribution and master planning is to determine aggregated transport quantities and to create specific distribution/transport plans. This planning has to consider estimated demand from sales department as well as available transport capacities, storage capacities, and filling levels. If necessary, distribution planning adjusts transport capacities in cooperation with third-party carriers. The planning horizon typically ranges from week to month. Short-term

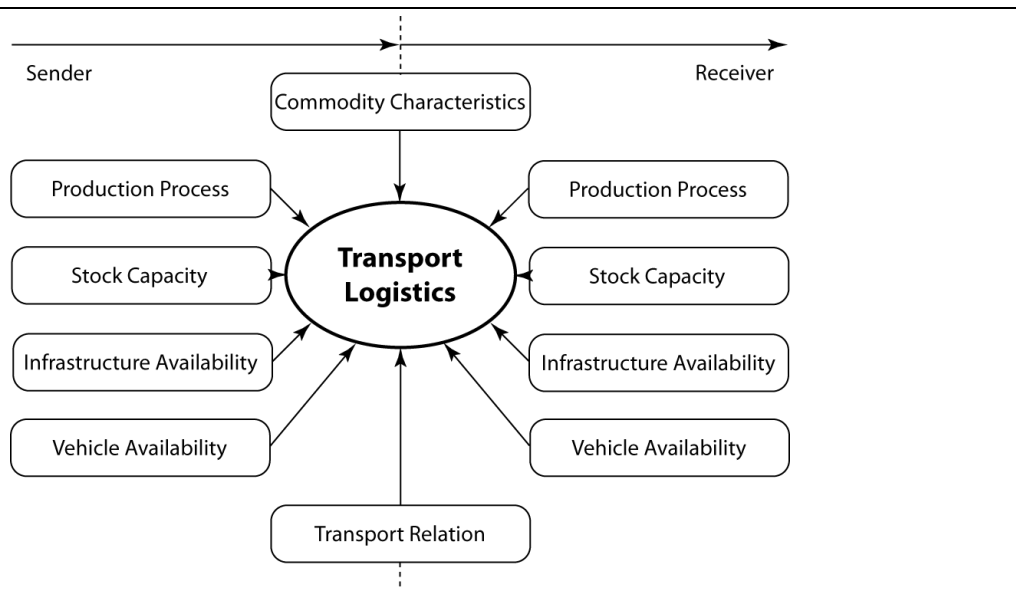
<sup>12</sup> Note that transport planning can be part of the distribution process of the supplier as well as of the procurement process of the receiver. Although the supplier is usually responsible for transport planning, there are important exceptions, e.g. in the automotive industry [FLEISCHMANN (2008)].

transport planning eventually schedules own transport capacities and/or places shipment orders to carriers and controls actual distribution.

In the further course of this study, there will be no distinction made between distribution and transport planning, as the boundaries are often fluent in rail freight business. The term “transport planning” will thus refer to both distribution and transport planning tasks.

Transport logistics faces numerous organisational and technical constraints (Figure 2-4). These constraints often differ between sender and receiver of a shipment and thus have to be considered separately.

**Figure 2-4: Constraints influencing transport logistics**



Source: FRIES (2010)

According to FRIES (2010), the most important constraints influencing the transport logistics are the specific characteristics of shipped commodities and transport relations. The size and nature of goods predetermine the general transport concept of a company. In addition, the more diverse the portfolio of shipped goods is, the more complex becomes transport management. The characteristics of goods also constrain the choice of transport modes in terms of required transport capacities, flexibility or transport speed. From a geographical point of view, all modes are basically available for any intra-European transport relations. However, transport distances can be a limiting factor for mode choices, as for short distances trucks are mostly the only competitive transport modes.

Further important constraints impacting transport logistics are the production process and stock capacity. They determine the necessary frequency and flexibility of the freight transport process. This is closely related to a major optimisation task in logistics planning: Finding the optimum between required inventory capacity and reliability of the transport chain in order to minimise total costs<sup>13</sup>.

<sup>13</sup> For details on logistics concepts please refer to SCHÖNSLEBEN (2004)

The other two constraints are the availability of infrastructure and vehicles. They may concern both the general transport logistics concept as well as concrete transport planning. The availability of infrastructure like rail sidings or transshipment terminals is a predetermining factor for choosing rail as transport mode. For specific transport planning, the availability of infrastructure is predominantly related to capacity issues. Vehicle availability is primarily linked to the question of outsourcing transports or not. If shipped commodities require special vehicles, it will be more difficult to find an appropriate third party logistic provider.

## **2.2.3 Collaborative Planning**

### **2.2.3.1 Introduction**

Collaborative planning has gained large prominence in supply chains during the last decade. This is based on the assumption that closer relationships and enhanced information exchange improves decision-making and reduces uncertainties in planning processes. According to DUDEK (2009), the idea of collaborative planning is “to connect planning processes [...] in order to exchange relevant data between the planning domains. The planning domains collaborate in order to create a common and mutually agreed upon plan”.

WHIPPLE AND RUSSEL (2007) have detected three types of collaborative relationships from exploratory interviews. They termed them “collaborative transaction management” (Type I), “collaborative event management” (Type II), and “collaborative process management” (Type III). Type I relationships are characterised by data exchanges and task alignments centred on operational issues within a short-term time horizon. Type II relationships represent a more intense form of collaboration, having a medium range time horizon and tactical focus. It is characterised by joint planning activities regarding events (e.g. promotions) or items (e.g. new products). Moving from purely exchanging information to joint planning requires a major shift in thinking, as trading partner’s input must be incorporated into decision processes. This shift paves the way to Type III of collaboration. It is differentiated by a strategic collaboration, which is characterised by joint problem solving, long-term joint business planning, and fully integrated supply chain processes. This requires building trust and setting joint business goals, which are only achievable through long-term oriented collaborations.

Typical objects of collaborations concern demand, inventory, and procurement planning [KILGER ET AL. (2008)]. A well-known approach for supply chain collaboration is *Collaborative Planning, Forecasting and Replenishment* [VICS (2004-1)]. It describes a sequence of steps and corresponding managerial guidelines to implement collaborations successfully. Yet, collaborations can also affect service-related objects like transportation. In transport collaborations, the customer is typically a manufacturer or retailer and the supplier a logistic provider. In order to promote this collaboration, VICS (2004-2) has

developed the concept of Collaborative Transportation Management. This concept will be discussed in the following chapter.

### 2.2.3.2 Collaborative Transport Management

More and more companies are adopting supply chain concepts attempting to reduce inventory investments and shorten order lead-time. This increases the requirements for all actors involved in the logistic chain. In this regard, carriers are often having difficulties to synchronise their assets with short-term customer demand. As a consequence, they have to maintain increased transport capacities to ensure required flexibility. This results in reduced productivity at carriers with negative effects on transport costs and prices. Besides, not including carriers in supply chain partnerships carries the risk of reduced quality performance, e.g. concerning on-time deliveries. This has a negative effect on the relationship of supplier and buyer of goods. ESPER AND WILLIAMS (2003) have listed a number of advantages of collaborative transport planning and indicated the beneficiary parties (Table 2-3).

**Table 2-3: Advantages of collaborative transport planning**

Metric	Examples	Beneficiary
Reduced transportation costs	Reduction of dwell times	Carrier; Buyer
Increased asset utilisation	Reduction of unpaid empty miles	Carrier
Improved service levels	Higher on-time performance	Supplier; Buyer
Increased visibility	Localization of freight in supply chain	Supplier; Carrier; Buyer
Improved end-customer satisfaction	Increased number of “perfect orders”	Supplier; Buyer
Increased revenues	Improved fully loaded miles	Supplier; Carrier; Buyer

Source: ESPER AND WILLIAMS (2003)

Including carriers in supply chain collaborations is apparently advantageous for all actors. To support this development, VICS (2004-2) has elaborated the concept of *Collaborative Transportation Management* (CTM). It consists of generic process descriptions as well as implementation guidelines. Its objective is to improve the operating performance in transport planning through a closer collaboration between shipper and carrier. CTM is divided into three distinct phases:

*Strategic phase:* Before engaging in collaborative transportation, trading partners must first agree on critical elements of their relationship and the involvement of carriers. On this basis, the responsible party for managing the relationship with carriers concludes the service agreements. This comprises elements like pricing, service expectations, depth of information sharing, and specification of collaborative processes.

*Tactical phase:* The tactical phase is a cyclical process and focuses on shipment planning requirements. It starts with a product/order forecast, which is converted to a shipment forecast by using pre-determined load building strategies. This shipment forecast should be shared with all parties of the relationship. This helps carriers adjust their planned

capacities by having an advanced look at the probable shipping volume. The key question is centred on the timing of this process. The determination of how long in advance a carrier needs to know the characteristics of shipment (e.g. ship date, ship from, ship to) will vary among carriers. The answer depends upon the carrier's flexibility in redistributing assets. The same goes for the owner of the relationship (shipper or receiver) whose ability to deliver this information varies as well. If a carrier is unable to fulfil the shipping requirements, other solutions are checked such as changing delivery requirements or using alternative carriers. As the shipping time horizon narrows, the forecasts transmitted to carriers become more and more accurate.

*Operational phase:* The operational processes comprise all activities for executing firm transportation orders. As soon as the carrier accepts shipment tenders, the exact times at shipper and receiver locations are scheduled and shipping resources assigned. Shipment tracking and freight accounting are further tasks of this phase.

Several studies have been conducted within the scope of CTM. They can be grouped in two main areas of research. One research focus consists in determining the actual benefit of CMT on the basis of industrial case studies. The studies of YUAN (2006 and 2007) belong to this category. He analysed the relationship between CTM and business performance and how CTM influences the behaviour of supply chains. The analyses based on the application of CTM to global logistics with emphasis on the information technology industry in Taiwan. The results show a positive effect on the overall transportation capacity utilisation as well as on the reduction of transportation costs. Other studies applied CTM in global logistics chains [TYAN AND WANG (2003)] or to a national logistic provider with focus on truckloads and intermodal shipments [ESPER AND WILLIAMS (2003)].

The second research focus concentrates on elaborating mathematical models for quantifying the costs and finding key performance indicators on a theoretical level (e.g. CHAN AND ZHANG (2011), FENG ET AL. (2005), ÖZENER AND ERGUN (2008)). This field of research is not in the scope of this study and was thus not analysed any further.

Only little scientific attention has yet been paid to CTM in rail freight. NAGEL (2008) evaluated the integration of rail transports into freight transport logistics chains of logistics service providers on a strategic level. She analysed different organisational models and described general performance requirements by means of interviews with freight railways and logistic service providers. Another project has developed different technical approaches for a better integration of freight railways into the logistic chain [CLAUSEN AND KOCHSIEK (2008)]. New technical transport concepts have been designed and IT-solutions were developed in order to improve the internal coordination of production resources allowing a shorter response time for shipping requests. Eventually, the industrial-driven project INTERTRANS (2010) has focused on integrating transport requirements in the production planning of the automotive industry. In combination with a

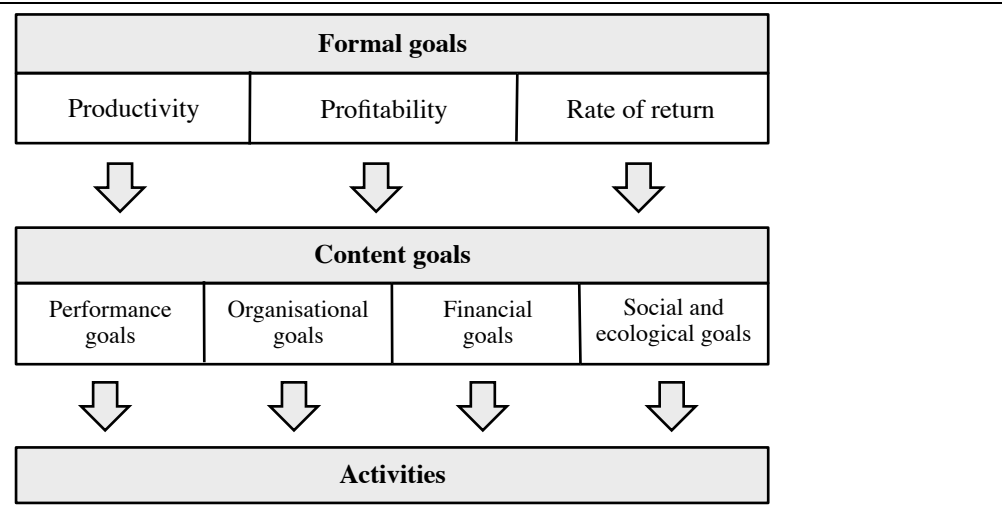
sophisticated transport planning, it aims to shift goods from road to rail by means of levelled transport peaks and larger shipment lots.

## 2.3 Characteristics of Productivity

### 2.3.1 General Term and Function

Productivity is one of the basic variables for governing production activities economically and represents an important factor for sustainable profits. Productivity therefore plays a crucial role at companies. In this regard, JUNG (2006) classifies productivity – together with profitability and rate of return – as a formal goal of a company (Figure 2-5). Formal goals are used for determining subordinate content goals such as volume of sales or the degree of company-internal value-add.

**Figure 2-5: Productivity in context with other company goals**



Source: JUNG (2006)

There are various ways how people view and define productivity. SMITH (1995) points out that each business field such as accounting, economics, or engineering has its own perception of productivity. Literature defines productivity generically as ratio between the output of a production or service system and the input needed to create this output (e.g. JUNG (2006), PROKOPENKO (1987)). A more specific definition of productivity is given by RANFTL (1978). He regards productivity as “... the efficiency and effectiveness with which resources – personnel, machines, materials, facilities, capital, time – are utilized to produce a valuable output”.

SCHERMERHORN (1986) also proposes the use of efficiency and effectiveness for describing productivity. In his perception, productivity is a result of both efficiency and effectiveness. Numerous concepts have been developed over the years to distinct these two terms from each other<sup>14</sup>. This study will use the definitions of HOFER (1984) who

<sup>14</sup> For details please refer to HAUBER (2002)

describes effectiveness as “the degree to which the actual output of the system correspond to its desired outputs” and efficiency as “the ratio of actual outputs to actual inputs”:

$$\text{effectiveness} = \frac{\text{desired output}}{\text{actual output}} \quad (2.1)$$

$$\text{efficiency} = \frac{\text{actual output}}{\text{actual input}} \quad (2.2)$$

DRUCKER (1980) concisely describes efficiency as “doing things right” and effectiveness as “doing the right things”. In other words, efficient acting is doing something better what is already being done, while effective acting provides the right services or products to market at the right time. For high productivity, both aspects must be fulfilled. Effective measures are of little value, if they are accomplished inefficiently and conversely, efficient actions make no sense if the output is not needed.

Eventually, there is a clear difference between productivity and profitability. Literature consistently defines profitability as the ratio of revenue and costs (e.g. JUNG (2006), KORNDÖRFER (2003), THOMMEN (2008)). It is therefore – in contrary to productivity – always non-dimensional. Besides, productivity does not necessarily correlate with profitability. Profit can be generated through price recovery even though productivity may have gone down. On the contrary, efficiently produced goods do not necessarily go with high profits if there are no customers buying them.

### 2.3.2 Types of Productivity Measurement

Productivity can be measured with different types of ratios. Literature typically distinguishes partial-, multiple-, and total-factor productivity ratios [SMITH (1995)]. Total-factor productivity ratios are the most aggregated form of productivity measurement. They integrate all kinds of input and output factors into a single index to describe productivity from an overall perspective. Such indices are often used for comparing the performance of companies or nations.

However, the expressiveness of such total-factor productivity ratios is limited for planning and controlling at companies [JUNG (2006)]. This is why companies apply partial-factor productivity ratios in a wide range of operations. Simply stated, partial-factor productivity ratios represent ratios of a total output divided by a single unit of input. A difficulty of using partial-factor productivity ratios is the assignment of a total output to a single unit of input. Hence, an improvement of one partial-factor productivity ratio might be achieved at the expense of another. This must be taken into account when creating a well-balanced set of partial-factor productivity ratios.

### 2.3.3 Productivity in Rail Freight

Most academic studies dealing with rail freight productivity concentrate on the elaboration of mathematical methods to generate total productivity indices, using public information such as net-tons-km or the number of locomotives (e.g. DE JORGE-MORENO

(1999), OUM AND WATERS (1999), LAN AND LIN (2006), YU AND LIN (2008)). These works are of little relevance for the scope of this study as the reasons for high/low productivity are not ascertainable with this approach. They were therefore not analysed in more detail.

There are only few studies, which use partial-factor ratios for describing productivity of freight railways. CHRISTOPH ET AL. (2006) propose an set of 28 key performance indicators for the corporate management of freight railways. Among them are also a number of aggregated productivity indicators such as revenue per employee, revenue per net-tons km, or the utilisation rate of transport capacities. Unfortunately the study does not address the question, which productivity indicators are most appropriate on the operational level. HILMOLA (2007) uses partial-factor productivity ratios like tons-km per locomotives or tons per track-km to compare the performance of European railways (both passenger and freight). However, the selection of these ratios shows no founded systematics and appears to be driven mainly by (public) data availability. Eventually WIEGMANS ET AL. (2007) carried out a similar benchmarking study on the efficiency of European Rail Freight Companies by means of 14 partial-factor ratios. The selection process of these ratios again remains rather unclear. The validity of the benchmarking results are thus at least questionable. Overall, literature provides no satisfactory answers on appropriate partial-factor indicators for measuring productivity at freight railways and how they are chosen systematically.



# 3 Research Hypotheses

---

This chapter introduces the general hypotheses of this study, which stand behind the research questions raised in chapter 1.2.

## 3.1 Need for Operational Collaborations

*Which operational processes are relevant for productivity at freight railways and would profit from collaborations with shippers? What information is needed at what time and in which quality?*

Existing literature does not give satisfying answers on the above questions. There are only few studies, which refer to rail freight processes. BERNDT (2001) provides an overview of rail freight tasks, yet on a fairly general level and with a function- rather than a process-oriented view (chapter 2.2.2.1). Besides, there are scattered literature sources describing freight wagon management (WURST (2004), WEYERS (2007), BEYGANG (2008), QGI (2010)) and crew scheduling (CAPRARA ET AL. (2006), CLAUSEN AND BAUDACH (2008)) in more detail. However, these studies keep process descriptions rather short, as they primarily serve as introduction for the elaboration of simulation tools or mathematical optimisation algorithms. These studies further make no reference to other rail freight processes and do not discuss the potential benefit of collaborations with shippers. Overall, there is no study providing a comprehensive process-oriented overview of operational processes at freight railways. Information about process durations, freedom for decision-making, and mutual dependencies are largely missing. As a consequence, the relevancy of operational processes for productivity and how they would profit from collaborations with shippers is still an open research question. Moreover, there is no standard approach available yet for consistently answering these questions with regards to freight railways.

*Hypothesis*

**The lack of operational collaborations with shippers hampers an efficient and effective operational planning at freight railways.**

This hypothesis will be verified in chapter 5 and 6.

## 3.2 Existing Capabilities at Shippers

*How is transport planning performed on shippers' side? What information is available at what time and in which quality? What affects planning quality?*

The principal tasks in distribution and transport planning are well described in literature (chapter 2.2.2.2). However, existing literature has not yet answered the question of how shippers in different rail transport sectors actually perform transport planning on the operational level. As a result, it is also unknown what information is available at what time and in which quality at rail-based shippers.

Literature describes numerous determinants on the level of transport logistics organisation [FRIES (2010)], supply chains [MEYER AND STADTLER (2008)] [SCHICK (2009)], and company logistics [SCHÖNSLEBEN (2004)]. All three topics have an impact on transport planning. As this impact is not specifically indicated however, there is still a gap in research about factors largely determining the design and output of rail transport planning. Further, no generic and cross-sectoral classification system is available yet to categorise shippers from the perspective of transport planning.

*Hypothesis*

**Transport sectors dispose of unshared planning information, which are valuable for freight railways.**

This hypothesis will be verified in chapter 7 and 8.

## 3.3 Feasibility of Implementation

*Which forms of operational collaborations qualify to be implemented between shippers and freight railways and what is the effect on freight rail productivity?*

Collaborative transport planning is a field of research, which has attracted considerable attention in the United States and in the Asian region. VICS (2004-2) has elaborated the basic concept of Collaborative Transportation Management (chapter 2.2.3.2), on which many studies are referring to. For instance, TYAN AND WANG (2003) and YUAN (2006/2007) have applied this approach for global logistics chains, while ESPER AND WILLIAMS (2003) conducted on this basis a case study about a national logistic provider with focus on truckloads and intermodal shipments. They all suggest a positive effect on productivity. Previous research has also concentrated on elaborating generic mathematical models for quantifying the costs and finding key performance indicators of such collaborations (CHAN AND ZHANG (2011), FENG ET AL. (2005), ÖZENER AND ERGUN (2008)). WHIPPLE AND RUSSEL (2007) have further elaborated three types of collaborative approaches, reflecting different intensities and objectives of collaborations on a generic level (chapter 2.2.3.1).

Only little scientific attention has yet been paid to collaborative transport planning in rail freight. NAGEL (2008) evaluated the integration of rail transports into freight transport

logistics chains of logistics service providers on a strategic level. Other studies have focused on a better integration of freight railways into the logistic chains by means of technical innovations [CLAUSEN AND KOCHSIEK (2008)] or adjusting production processes for a better conformance with freight rail requirements [INTERTRANS (2010)]. However, no literature was found dealing with implementable forms of operational collaborations in freight rail, by integrally considering the needs of freight railways and capabilities at shippers. This missing integrated view on the operational level is regarded as a substantial gap in current rail freight research.

*Hypothesis*

**There are implementable forms of operational collaborations between shippers and freight railways, which have a positive effect on freight rail productivity.**

This hypothesis will be verified in chapter 9, referring back to the results elaborated in previous sections of the study.

# 4 Research Methodology

---

## 4.1 Methodological Concept

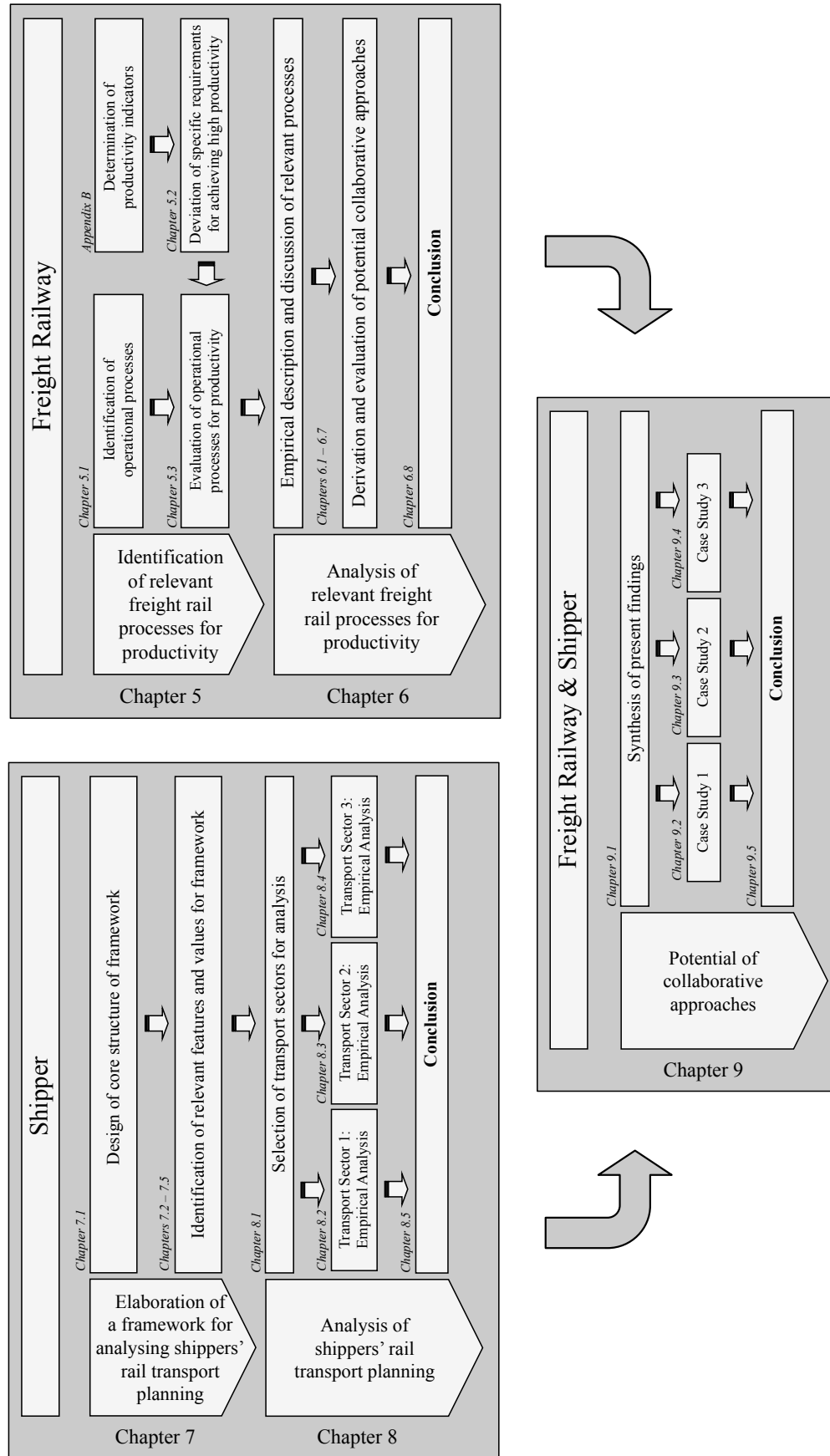
In order to verify the hypotheses formulated in chapter 3 the research was structured as illustrated in Figure 4-1.

The right column in Figure 4-1 represents the research approach on freight railway's side and is dedicated to verify the first hypothesis that a lack of operational collaborations with shippers hampers an efficient and effective operational planning at freight railways. The first step will consist in the identification of relevant operational processes. For that, meaningful productivity indicators are determined by means of a self-developed framework. On this basis, generic requirements for high productivity are derived at freight railways. This allows evaluating the relevancy of operational processes on productivity. The most relevant processes are then selected for an empirical analysis and discussion, revealing promising collaborative approaches from the perspective of a freight railway.

The left column in Figure 4-1 represents the research approach on shippers' side and is dedicated to verify the second hypotheses that transport sectors dispose of unshared planning information, which are valuable for freight railways. Based on quantitative data analyses, three transport sectors will be selected for further analyses, which are particularly challenging for planning. For these sectors, transport-planning processes as well as decisive influencing factors are identified and described empirically. A self-developed generic framework ensures consistent and comparable analyses for all transport sectors and shippers. The results of these quantitative and qualitative analyses reveal and explain the range of possibilities at analysed transport sectors for operational collaborations with freight railways.

Gained results from shipper and freight railway side are eventually synthesised, disclosing the actual potential for collaborative approaches. Cases studies on three promising collaborative approaches estimate the quantitative benefit and describe needed organisational changes and incentives for shippers. These results are used to verify the third hypothesis that there are implementable forms of operational collaborations between shippers and freight railways, which have a positive effect on freight rail productivity.

**Figure 4-1: Methodological concept**



## 4.2 Applied Methods

### 4.2.1 Modelling of Planning Procedures

#### 4.2.1.1 Methods Overview

The international standard organisation ISO and the European Committee for Standardisation CEN have produced a set of standards to ensure a common understanding of modelling [KOSANKE (2005)]. From the listed concepts used in methodologies and reference architectures, ARIS<sup>15</sup> appears as the most appropriate one for the scope of this study. ARIS is a comprehensive framework concept for the management of business activities, which has widely been applied in industrial companies for many years. SCHEER (1992) has developed the root theory of ARIS in the early nineties to describe information systems. The concept distinguishes, inter alia, four descriptive views, which SEIDLMEIER (2004) describes as follows:

- **Function View:** A function is a technical task or activity that is intended to support one or several business goals. As a rule, it describes the occurrence of an information object after which an action is carried out in response to it – for example, to schedule a job order, or to process a complaint. Function trees and objective diagrams are typical representatives of pure function views.
- **Data View:** The data view is the logical data structure of an application case. Entities, attributes, and relations primarily create this structure. Entities are real or abstract things that are of interest for the viewed part of a task. Attributes are concrete characteristics of these entities, whereas relations show the logical correlations between these entities. This data view has a large significance in the field of software development.
- **Organisation View:** The organisation view structures the tasks of an enterprise, the individuals performing those tasks, and the relationships within the enterprise. Organisational units are responsible for the functions required to reach certain business goals. The organisation chart as a typical example of a pure organisation view is one of the most common models in companies.
- **Process View:** The process view resolves the connection between the function, data, and organisation views. Models with a process view primarily describe the (temporal logical) connection of functions, in contrast to static function and data models. Process models are widely used at companies to describe business processes on all levels of detail.

Due to the high complexity of most business activities, it is generally not possible to depict the system to be analysed in one single model. That is why most models are

---

<sup>15</sup> ARIS = Architecture Integrated Information Systems

focusing on certain aspects of a system. Depending on the modelling objective, different methods come into consideration.

SPECKER (2005) postulates that modelling methods can be grouped by their primary and secondary view, which consequently leads to a matrix of 16 fields. Table 4-1 shows this matrix together with a number of established modelling methods. Methods with a “pure” view are found in the diagonal axes of the matrix, whereas methods in the other fields combine two different views<sup>16</sup>.

**Table 4-1: Classification matrix of modelling methods**

primary secondary	Process View	Function View	Data View	Organisation View
<b>Process View</b>	<i>Process map</i>	<i>Package diagram</i>	<i>State transition diagram</i>	<i>Task oriented information flow</i>
<b>Function View</b>	<i>Flowchart; Event driven process chain</i>	<i>Function tree; objective diagram</i>	<i>Class-responsibilities collaborators</i>	
<b>Data View</b>	<i>Sequence diagram</i>	<i>Data flow diagram</i>	<i>Entity relationship model; Object diagram</i>	
<b>Organisation View</b>	<i>Activity diagram; Business process modelling notation</i>	<i>Use-case diagram</i>	<i>Collaboration diagram</i>	<i>Organisation chart</i>

Source: SPECKER (2005)

#### 4.2.1.2 Applied Methods

This study will describe the temporal sequence of activities in transport planning at both shippers and freight railways. A **process-oriented view** is therefore chosen as general approach for these analyses.

The generic identification of operational processes at freight railways can methodically be conducted with a **process map**, starting from the primary output of railways – running trains – and disclosing in reverse temporal logic needed planning activities (chapter 5.1). This pure process modelling method will not be sufficient for the empirical analyses in chapters 6, 8, and 9, as on this level of detail functional and organisational aspects become relevant as well. Referring to Table 4-1, four modelling methods fulfil these requirements: The flowchart, the event driven process chain, the activity diagram, and the business process modelling notation. As all standard elements of flowcharts are integrated in the other three – more recent – modelling methods, flowchart diagrams are not considered any further. For the remaining three modelling methods, a detailed description and comparative evaluation has been conducted in Appendix A. It shows that the

<sup>16</sup> In some modelling methods, even a third or fourth view can be identified. However this often leads to overcrowded diagrams and high complexity.

**Business Process Modelling Notation (BPMN)** is the most appropriate modelling method for the purpose of this study. For one, BPMN is comprehensive and largely intuitive with a distinct process view. For another, it has a wide range of formal semantics. The weakness of BPMN mainly consists in the limited possibilities for describing data objects in processes. Results of quantitative data analyses are therefore difficult to integrate in this model.

## 4.2.2 Impact Analyses on Planning and Productivity

### 4.2.2.1 Methods Overview

Impact analyses are needed twofold in this study: For one, the impact of operational planning tasks at freight railways on productivity has to be assessed methodically (chapter 5). For another, a large number of impact factors will expectedly be disclosed during empirical analyses of transport planning at shippers (chapter 8). This requires a systematic and comparable description method.

In view of these tasks, a number of different methods are worth considering. A possible method is the influence matrix methodology. It is used to analyse complex problems and provide insights into complex system structures, functions, and behaviours [COLE (2006)]. The objective is to individually discuss and evaluate the influence of key factors characterizing the system to be analysed. It supports an efficient and straightforward discussion about the driving issues that determine the system.

The initial influence matrix was developed by GORDEN AND HAYWARD (1968) and later simplified by VESTER (1976). The four main steps involved in building an influence matrix are

- problem definition,
- factor selection,
- matrix scoring, and
- matrix evaluation.

First, the research problem and system limits have to be defined. The system is then determined with a set of relevant key influence factors. An assessment of interrelations between selected factors is carried out by means of a matrix to understand the influence exerted and received by each factor (Figure 4-2). This matrix facilitates a systematic assessment of every single interrelation and intensity. For the scoring of these interrelations, VESTER AND HESLER (1982) propose a simplified scoring strategy that quantifies the influence on a scale of 0, 1, 2, and 3 (no impact, weak impact, medium impact, strong impact). After the completion of this comparative scoring, rows and columns are summed up, giving evidence about the significance of each factor<sup>17</sup>.

---

<sup>17</sup> For more details please refer to SIMON (2005)



Figure 4-2: Exemplary influence matrix

	Climate & Atmosphere	Pest Management	Maintain Biodiversity	Maintain Integrity of Ecological Processes	Maintain Soil Health	Natural Accumulation & Purification	Landscape Change Processes	Water Quality & Supply	Scientific Research	Customary Use	Economic Drivers	Economic Inputs	Income Tax & GST	Labour Market	Primary Industries	Property Valuation	Secondary Industry	Tertiary Sector	Family & Community Wellbeing	Human Health	Participation in Economic Life	Population Dynamics	Public Life - Governance	Community Services	Tourism, Leisure, Recreation, Sport	Governance of Social Institutions	Policy, plans, rules, legislation	Non-Local Influences
Climate & Atmosphere	2	3	3	4	4	3	4	3	2	2	2	2	2	4	3	2	2	2	3	3	2	2	2	4	1	2	1	
Pest Management	0	3	4	3	3	2	3	3	2	2	2	3	2	1	3	3	2	1	2	3	2	2	1	1	2	2	3	2
Maintain Biodiversity	2	2	4	3	3	3	3	3	2	2	2	2	3	3	2	2	2	2	2	2	2	2	1	3	2	3	2	
Maintain Integrity of Ecological Processes	3	2	3	3	4	3	2	4	3	3	2	2	1	1	3	2	2	2	3	3	2	2	2	1	3	2	3	2
Maintain Soil Health	2	2	3	3	3	3	4	3	2	2	2	1	2	4	3	2	1	3	3	2	2	1	2	2	1	3	2	
Natural Accumulation & Purification	4	2	3	3	4	2	2	3	2	2	1	1	1	1	2	2	2	1	2	3	1	1	1	1	2	1	3	2
Landscape Change Processes	2	2	2	2	3	2	2	2	2	2	2	1	1	2	3	2	2	1	1	2	2	1	2	2	1	3	2	
Water Quality & Supply	3	1	3	4	3	2	3	3	3	3	3	3	2	3	4	4	4	4	2	3	3	2	2	2	3	2	3	2
Scientific Research	2	4	3	3	3	2	3	2	1	1	3	1	2	4	3	4	3	4	3	2	3	1	1	1	2	2	4	2
Customary Use	0	1	2	2	1	2	2	2	3	3	1	1	0	1	1	1	2	2	2	2	2	1	2	1	2	1	2	1
Economic Drivers	2	2	2	2	1	1	2	2	1	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	3
Economic Inputs	2	2	2	2	3	1	3	3	2	2	3	2	3	3	4	4	4	3	3	2	3	3	3	3	3	2	2	2
Income Tax & GST	1	2	1	1	1	1	1	2	1	3	3	1	3	4	2	3	3	3	3	2	2	2	2	3	2	3	3	2
Labour Market	1	2	2	1	1	1	1	1	1	2	3	3	2	4	2	3	3	3	2	3	3	2	3	3	3	2	3	1
Primary Industries	3	4	4	3	4	3	4	4	2	2	4	3	3	3	4	4	3	4	2	3	3	3	3	3	3	3	3	2
Property Valuation	1	2	2	1	1	1	2	2	1	1	2	2	2	2	2	2	2	3	2	3	2	2	2	2	2	2	3	2
Secondary Industry	2	1	2	2	2	2	3	3	1	2	3	3	4	3	3	3	3	3	3	3	3	3	3	3	3	2	3	2
Tertiary Sector	1	1	1	1	1	0	1	2	2	1	2	2	2	2	2	2	2	2	3	4	2	3	2	3	3	2	2	2
Family & Community Wellbeing	1	2	2	2	2	2	3	2	1	2	2	2	3	2	2	3	2	2	2	4	3	3	2	3	3	3	3	2
Human Health	1	2	2	2	1	1	2	2	2	1	2	2	3	3	2	3	3	3	4	3	3	3	3	3	2	2	2	1
Participation in Economic Life	1	1	2	2	1	1	2	2	2	2	3	3	4	3	2	3	3	3	3	2	4	3	3	3	2	2	3	2
Population Dynamics	2	2	2	2	2	2	2	2	2	2	2	2	2	4	3	3	3	3	4	3	3	2	3	3	3	2	2	2
Public Life - Governance	2	3	3	2	2	2	3	3	2	1	2	2	2	3	3	3	3	3	4	3	3	3	3	3	3	3	3	2
Community Services	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2	2	2	3	4	3	3	3	3	3	3	3	1
Tourism, Leisure, Recreation, Sport	1	2	2	2	1	1	2	3	1	1	2	2	3	3	3	3	3	3	3	3	3	3	3	3	2	2	3	2
Governance of Social Institutions	2	3	3	4	2	3	3	4	3	2	2	3	3	3	3	3	3	3	3	3	3	3	4	3	3	4	2	2
Policy, plans, rules, legislation	3	4	3	3	3	3	3	4	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2
Non-Local Influences	2	3	3	2	2	2	2	2	2	1	3	3	3	3	4	3	3	3	3	3	2	3	3	3	3	3	3	3

Source: COLE (2006)

Based on the basic idea of the influence matrix methodology, GOMEZ AND PROBST (1995) have developed a comprehensive method for analysing complex systems. It allows modelling systems with a high degree of mutual dependencies and feedback effects as well as temporal variances and dynamic behaviours.

A different method for describing and analysing influencing factors of a system is the morphological analysis. Fritz Zwicky developed this method in the 1940es to “structure and investigate the total set of relationships contained in multi-dimensional, non-quantifiable, problem complexes” [RICHEY (1998)].

Its idea is to break a certain subject down into a number of basic features that describe the subject as completely as necessary [WISSEMA (1976)]. The various values that each feature can take are then identified. This approach opens up a field of possibilities and new options are brought to attention that might have been ignored otherwise<sup>18</sup>.

Morphological analyses have been applied to many diverse subjects. In the field of logistics morphological schemes have been created to describe both in-house logistic planning [SCHÖNSLEBEN (2004)] and to characterise supply chains between manufacturing companies [MEYER AND STADTLER (2008)]. Figure 4-3 exemplarily shows an application scheme of morphological analysis. Advantageous is the possibility to arrange the values for each feature so that the expected suitability for a certain situation is increasing from left to right (in Figure 4-3: suitability for simple techniques of planning & control). This can be regarded as another form of impact analysis.

<sup>18</sup> For this reason morphological analysis is also an important creativity technique.

**Figure 4-3: Exemplary scheme for morphological analyses**

Features referring to user and product or product family					
Feature	Values				
Frequency of consumer demand	unique		block-wise (sporadic)	regular	continuous
Product concept	according to (changing) customer specification	product family with many variants	product family	standard product with variants	individual or standard product
Features referring to logistics and production resources					
Feature	Values				
Physical organization of the production infrastructure	site or project production	island or group production	job shop production	interrupted line flow production	flow shop production
Features referring to production or procurement order					
Feature	Values				
Reason for order release (type of order)	demand/(prod. / proc. to customer order)			prediction / (forecast order)	use (stock replenishment order)
Frequency of order repetition	non-repetitive (production / procurement)		(production / procurement) with infrequent repetition		(production / procurement) with frequent repetition

Increasing degree of suitability for simple techniques of planning & control

Source: SCHÖNSLEBEN (2004)

### 4.2.2.2 Applied Methods

On the freight railway side, impact analyses are necessary to evaluate the relevancy of operational planning processes on productivity (chapter 5). Their impacts on productivity will generally not be quantifiable but has to be estimated qualitatively on the basis of numerous individual requirements. The **influence matrix methodology** is well suited for this kind of problem. This method is very efficient to identify and substantiate the relevant operational processes and requirements for productivity with limited resources. To fit the specific need of its application in chapter 5, the method will have to be modified in one aspect. The influence matrix in this study does not evaluate the influences of factors on each other but unidirectional assesses the influence of operational planning processes on a large number of individual requirements for high productivity. The simple qualitative scoring system helps focus on critical factors and processes, but will not be able to give a detailed ranking and comprehensive conclusions about the analysed system. This method is therefore a preliminary step only for the subsequent detailed system modelling in chapter 6. The influence matrix methodology is further prone to a certain degree of subjectivity, due to its qualitative character. This is countered with a high transparency of underlying arguments, as the scoring is done specifically to individual requirements and so are the arguments.

On shipper side, impact analyses are primarily necessary to classify and evaluate impact factors on transport planning. These impact factors can be from the same type at analysed transport sectors and shippers but could show different manifestations. While this would be difficult to illustrate with an influence matrix, the **morphological analysis method** is designed to meet precisely this need. The impact analysis is easily realised by sorting the individual values of impact factors in the respective morphological scheme according to the relevant questions in this study. The morphological analysis method will therefore be

used for the elaboration of a generic framework to analyse the major effects on transport planning at shippers (chapter 7). This morphological framework will then be used for the subsequent empirical analyses in chapter 8. A weakness of this approach is the unavoidable simplification of possible values. Some situations at shippers might therefore not unambiguously be depictable. In this case, a further subdivision of the concerned feature might be necessary. Analogue to the influence matrix methodology, the morphological analysis method is subject to certain subjectivity as well. The application of this method therefore requires a sound argumentation.

## 4.2.3 Gathering of Empirical Information

### 4.2.3.1 Methods Overview

Empirical information can be gathered by qualitative as well as quantitative research methods. The differences between these two major research methods are briefly explained in the following:

*“Qualitative research* is multimethod in focus, involving an interpretive, naturalistic approach to its subject matter. This means that qualitative researchers study things in their natural setting, attempting to make sense of, or interpret phenomena in terms of the meanings people bring to them. Qualitative research involves the studied use and collection of a variety of empirical materials – case studies, personal experiences, interviews, and observational texts [...] – that describe the subject of research” [DENZIN AND LINCOLN (1994)].

*“Quantitative research* uses numbers and statistical methods. It tends to be based on numerical measurements of specific aspects of phenomena; it abstracts from particular instances to seek general description or to test causal hypothesis; it seeks measurements and analyses that are easily replicable by other researchers” [KING ET AL. (1994)].

In short, qualitative research emphasises on processes and meanings that are not (rigorously) measured in terms of quantity, amount, intensity, or frequency, while quantitative research focuses on the measurement and analysis of causal relationships between variables, not processes [DENZIN AND LINCOLN (1994)].

The choice of quantitative or qualitative research methods depends on the individual application. Qualitative methods are suited for situations requiring a differentiated and comprehensive description of opinions and impressions [WINTER (2000)]. Notably for the identification of underlying causes of a certain situation and for the elaboration of generic typologies, qualitative research is an ideal approach. It provides the needed room of flexibility and openness to disclose and interpret yet unknown correlations. In turn, quantitative methods are well suited for an objective measurement and quantification of issues by means of a large quantity of data samples and statistical test procedures. The comparison of data over time and derived predictions of future development are ideal fields of application for quantitative methods.

In the field of qualitative research, open-ended interviews are a major instrument to collect needed data. PATTON (2002) distinguishes between

- the informal conversational interview,
- the general interview guide approach, and
- the standardised open-ended interview.

These three approaches differ to which extent interview questions are determined and standardised before the interview occurs.

The *informal conversational interview* relies entirely on the spontaneous generation of questions in the natural flow of an interaction. It is also called “unstructured interview” and offers maximum flexibility to pursue information in whatever direction appears to be appropriate. A weakness of informal conversational interviews is that it may require a lot of time to collect systematic information. Further, data obtained can be difficult to pull together and to analyse, because different questions will general different responses.

The *general interview guide approach* involves outlining a set of issues that are to be explored with each respondent before interviewing begins. In this regard, the guide serves as a basic checklist during the interview to make sure that all relevant topics are covered. The interviewer remains free to build a conversation within a subject area, and to word questions spontaneously, but always with the focus on a predetermined subject. The advantage of an interview guide is to make interviewing a number of different people more systematic and comprehensive by defining the issues to be explored in advance. Such interview guides can be developed in more or less detail. It depends on which extent the interviewer is able to specify important issues prior to the interview and how important the necessity is to ask questions in the same order to all respondents.

The *standardised open-ended interview* consists of a set of questions carefully worded and arranged with the intention of taking each respondent through the same sequence and asking each respondent the same questions with essentially the same words. This ensures that each interviewed person gets the same stimuli. This is particularly important when a number of different interviewers are involved. Standardised open-ended interviews facilitate subsequent analyses by making responses easy to find and to compare. In turn, a major weakness of standardised open-ended interviews is the missing possibility for interviewers to pursue topics that were not anticipated when the interview was written.

GLÄSER AND LAUDEL (2009) name three basic approaches of how to conduct qualitative interviews:

- Face-to-face
- Telephone
- Email

They consider face-to-face interviews as the most valuable approach for gathering qualitative information. The primary advantages of telephone or email interviews are their cost and time efficiency. These methods are therefore well suited for covering a wide

geographical area and/or for a large number of interviews. In contrary to face-to-face interviews however, they provide no visual information, which could help classify provided information and efficiently control the course of conversation. Second, disturbances and “secondary works” during interviews are neither detectable nor avoidable. Third and last, they hinder respondents to hand over explanatory documents to the interviewer, which is facilitated with face-to-face interviews.

#### **4.2.3.2 Applied Methods**

In this study, empirical information will primarily be gathered through **face-to-face interviews**, using a **general interview guide approach** (chapters 6 and 8). This qualitative approach is complemented with **quantitative analyses** of transport planning outputs such as shipment forecasts and operated trains, supporting the classification and explanation of qualitative findings (chapter 8) and estimating the potential benefit of collaborative approaches (chapter 9).

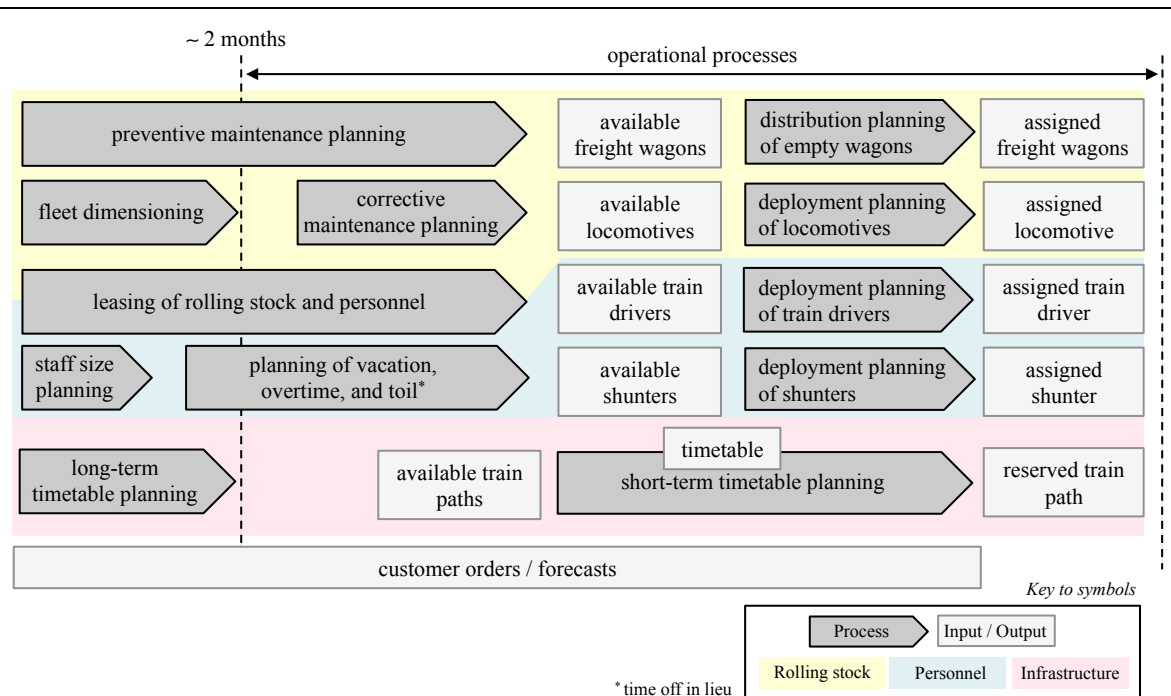
There are several reasons for pursuing a primarily qualitative research approach. Disclosing the procedures in transport planning of shippers and freight railways require a differentiated and comprehensive description rather than an objective measurement. It further requires a high degree of flexibility to cope with any kinds of possible planning situations, which are unknown in the beginning. This also explains the choice of the general interview guide approach. The interviewer is free to build a conversation within the subject area of transport planning, and to word questions spontaneously, but keeps focused on the topic of interest with the prepared guideline. Besides, the interviews will be conducted and evaluated by the same person, ensuring a consistent interview procedure and interpretation without predefined detailed standard questions. Using a qualitative research approach is eventually well suited to identify yet unknown underlying causes of certain behaviours in current transport planning, which would not be possible with quantitative analyses.

# 5 Identification of Relevant Freight Rail Processes for Productivity

## 5.1 Operational Processes at Freight Railways

This chapter identifies the operational processes at freight railways on a generic level. The primary output of railways – moving trains – has been chosen as starting point for disclosing precursor planning activities in a logical sequence. Moving trains integrate all forms of inputs with relevance to planning, such as physical transport resources, customer information, or timetables. This ensures getting a complete picture of planning activities at freight railways. The result of this approach is depicted in Figure 5-1 and explained in the following sections. Identified processes and associated inputs/outputs have been grouped to three classes: rolling stock, personnel, and infrastructure. With regards to railways, the regular bimonthly update of annual timetables appears as an appropriate time horizon for separating operational from tactical planning<sup>19</sup>. Tactical planning thus focuses/bases on the annual timetable and the bimonthly regular updates, while operational planning considers and manages any intermediate short-term modifications.

**Figure 5-1: Operational processes at freight railways**



<sup>19</sup> Dates of regular timetable updates are internationally coordinated and published under <http://www.rne.eu>

Locomotives, freight wagons, train drivers, shunters, and reserved train paths are the basic requirements for moving trains<sup>20</sup>. Each of these elements require distinct planning:

### ***Deployment planning***

Deployment planning assigns locomotives, train drivers, and shunters to specific trains. In accordance with CAPRARA ET AL. (2006), this study defines deployment planning as “the building of work schedules for assets needed to cover a planned timetable”. This task can be divided into duty scheduling and asset rostering. During duty scheduling, a convenient set of duties is being constructed. Their length is generally no longer than one or two consecutive days. A feasible duty represents a sequence of trips, breaks, and transfers, which considers existing rules and restrictions. In the subsequent asset rostering, named individuals or specific locomotives are assigned to these duties. The application of computer-based optimisations tools is manifest. However this is still an exception in practice, although being a popular field of research [CLAUSEN AND BAUDACH (2008)]. Most existing products offer graphical front ends only to support the process of deployment planning.

### ***Timetable planning***

Reserved train paths require an underlying timetable. In turn, the elaboration of timetables at freight railways must consider the availability of train paths. The management of train-paths is therefore regarded as an integral part of timetable planning at freight railways. If a freight railway offers supply-oriented single wagonload services and demand-oriented block-train services, this process must have a distinct long-term and short-term part. In long-term timetable planning, annual timetables are elaborated for regularly operated trains and bimonthly updated during the year. This allows early reservations of train paths at rail infrastructure managers. The main task in short-term timetable planning is completing timetables with incoming (weekly) block train orders. In addition, changed transport demands may require modifications at already planned trains. On this basis, additional train paths have to be reserved or existing modified/cancelled. This is possible within hours and subject of extra charges [SBB (2010-1)]. This updated timetable serves as main input for subsequent deployment planning of locomotives, train drivers, and shunters.

### ***Distribution planning of empty freight wagons***

The provision of freight wagons to shippers is still a common service at freight railways, notably in association with single wagonload services. This implies the large numbers of freight wagons at most of (incumbent) freight railways in Europe. Distribution planning of empty freight wagons is thus another important operational process at freight railways. Its main task is to provide requested empty wagons timely to shippers at minimum costs [BEYGANG (2008)]. Major cost drivers are transport distances and shunting costs. This

---

<sup>20</sup> The supply of energy supply is an integrated part of train-path reservations in Switzerland and therefore not listed separately [SBB (2010-1)].

complex optimisation problem is predestined to be solved by computer-based algorithms. At SBB Cargo, for example, this has been common practice for many years [BAYER (2005)]. The management of imminent wagon shortages will be another important task of distribution planning of empty wagons. Prioritizations of freight wagon orders, consultations with customers about possible shifts of freight wagon orders, or the active reduction of idle times of needed freight wagons at customers can be necessary options to solve this problem.

The number of available rolling stock and personnel is an important planning input for the above-described processes<sup>21</sup>. Several preceding processes actively influence this number.

### ***Preventive and corrective maintenance planning***

A certain percentage of rolling stock is always unavailable for deployment, due to technical maintenances. Preventive and corrective maintenance planning are therefore two processes with influence on the number of available rolling stock. For TELANG AND TELANG (2010), preventive maintenance comprises “all actions initiated to prevent or at least to reduce the probability of occurrence of failures”. In this context, preventive maintenance planning has two main tasks. First, it establishes time- or distance-dependant preventive maintenances cycles. This task is clearly strategic and thus out of the scope of this study. Second, preventive maintenance planning must also schedule due rolling stocks in free time slots at repair shops. Ideally, this is done during times of low traffic demand. Such preventive maintenances notably concern locomotives, having numerous maintenance cycles, ranging from a few weeks (small preventive maintenances) to years (major revisions)<sup>22</sup>. Corrective maintenance can be defined as “maintenance carried out after failure has occurred” [TELANG AND TELANG (2010)]. Corrective maintenance planning will therefore primarily comprise the priority setting of repairs and the organisation of inbound transports to repair shops. Evidently, the planning horizon of corrective maintenance will be very short. From the author’s experience, not all damages at rolling stock are relevant for a safe operation and thus require immediate repair. This gives additional flexibility in planning of damaged rolling stock.

### ***Planning of vacation, overtime, and time off in lieu (toil)***

Planning of vacation, overtime, and time off in lieu (toil) influences the number of available employees. Mandated overtime work increases the number and performance of available personnel at times of high demand. In turn, vacation and time off in lieu should coincide with times of low demand. It is assumed that vacations of employees are

---

<sup>21</sup> European Norm 50126 defines availability as “the ability of a product to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval [e.g. at high demand] assuming that the required external resources are provided”.

<sup>22</sup> In Switzerland, railways are responsible for the safe operation and maintenance of their vehicles (Art 10, Eisenbahnverordnung). This includes maintenance plans, which may therefore differ between companies. According to a statement of a Swiss engineering company in 2009, the most frequent preventive maintenance type (“P1”) is typically due every 10’000 km for modern freight locomotives.



generally determined earlier than three months in advance, thus being out of the scope of this study. However, planning of overtime and time off in lieu will be a clear operational task, as it is a response to actual or expected transport demand.

### ***Leasing of rolling stock and personnel***

Freight railways have also the possibility to vary the number of available rolling stock and personnel by leasing them from or to third parties. Leased rolling stock and personnel are more expensive than in proprietary possession. However, they are more flexible and can specifically be used for covering peak demands. The main task of leasing activities is therefore to find an optimum mix of own and leased rolling stock/personnel to minimize total costs. This is possible on a strategic as well as on the operational level. Leasing is common practice for freight wagons with a total of more than 130'000 leased freight wagons in Europe [GILLIAM (2008)]. Analogue leasing activities do also exist for train drivers and locomotives, yet on a significant lower level.

### ***Fleet dimensioning and staff size planning***

Fleet dimensioning and staff size planning complete the picture of planning processes, which influence the number of rolling stock and personnel at freight railways. These strategic processes are responsible for major procurements/scraping of rolling stock and employments/dismissals of personnel. They typically rely on a long-term estimation of business development and are not in the scope of this study.

## **5.2 Requirements for High Rail Freight Productivity**

### **5.2.1 Approach**

The requirements for high rail freight productivity will be derived from fifteen partial-factor indicators comprehensively describing productivity at freight railways (Figure 5-2). Detailed preliminary analyses have shown that any measures improving one of these fifteen indicators contribute to higher productivity at freight railways (Appendix B)<sup>23</sup>. The major advantage of this approach is that relevant requirements for high productivity can be identified very specifically. Imagining an environment leading to a “perfect” indicator helps reveal the requirements for high productivity.

---

<sup>23</sup> See also MOLL AND WEIDMANN (2011)

**Figure 5-2: Proposed indicators for describing productivity at freight railways**

<b>Efficiency</b>	$\frac{\text{train-km}}{\text{train driver}}$	$\frac{\text{wagon-km}}{\text{freight wagon}}$	
	$\frac{\text{train-km}}{\text{main line locomotive}}$	$\frac{\text{no. of shipped wagons}}{\text{shunting locomotive}}$	$\frac{\text{no. of shipped wagons}}{\text{shunter}}$
<b>Effectiveness</b>	<i>single-wagonload service</i>		
	$\frac{\text{loaded freight wagon-km}}{\text{train-km}}$	$\frac{\text{loaded freight wagon-km}}{\text{shipped freight wagon-km}}$	
<b>Unit Costs</b>	$\frac{\text{main line locomotive costs}}{\text{main line locomotive}}$	$\frac{\text{shunting locomotive costs}}{\text{shunting locomotive}}$	$\frac{\text{freight wagon costs}}{\text{freight wagon}}$
	$\frac{\text{train driver costs}}{\text{train driver}}$	$\frac{\text{shunter costs}}{\text{shunter}}$	$\frac{\text{train path costs}}{\text{train-km}}$
<b>Earning Power</b>	<i>single-wagonload service</i>		
	$\frac{\text{revenue}}{\text{wagon-km}}$	<i>block train service</i>	
		$\frac{\text{revenue}}{\text{train-km}}$	

## 5.2.2 Discussion

### 5.2.2.1 Requirements for High Efficiency at Freight Railways

The efficiency of main line locomotives, expressed as *train-km per main line locomotive*, is at a maximum if they are operated at high speed, in single traction and with minimal idle time between operations. Minimal idle times require dense locomotive schedules, few unproductive transfers, long transport distances and a demand-oriented availability (Figure 5-3). The same requirements analogously apply for the efficiency of train drivers (*train-km per train driver*). High transport speed and minimal idle times are likewise essential requirements for high efficiency of freight wagons (*wagon-km per freight wagon*). In order to achieve minimal idle times of freight wagons, they are ideally constantly booked by customers and loading/unloading procedures at customers are further as short as technically possible.

**Figure 5-3: Requirements for high efficiency at freight railways**

<i>specific requirement</i>	<i>indicator</i>				
	train-km / main line locomotive	train-km / train driver	wagon-km / freight wagon	shipped wagons / shunter	shipped wagons / shunting locomotive
dense schedules for main line locomotives	█				
few and short locomotive transfers					
demand-oriented availability of locomotives					█
no multiple unit trainsets	█				
long transport distance		█			
high transport speed	█				
dense schedules for train drivers		█			
few and short train driver transfers					
demand-oriented availability of personnel		█		█	
demand-oriented availability of wagons			█		
short idle time of freight wagons at customer			█		
high rate of booked freight wagons				█	
dense schedules for shunters				█	
few delivery points per route				█	█
short delivery distance per route				█	█
several freight wagons per delivery				█	█
dense schedules for shunting locomotives					█

Shunters and shunting locomotives show different requirements to achieve maximal efficiency (expressed by the indicators *shipped wagons per shunter* and *shipped wagons per shunting locomotive*). Just as train drivers and main line locomotives, they require dense schedules and high availability. However, shunters and shunting locomotives are notably deployed for last mile deliveries in single wagonload service. Hence, an advantageous network design with few delivery points and short delivery distances per route, as well as a high number of shipped freight wagons per delivery are necessary too for achieving high efficiency. Besides, the network design also has a significant influence on service offers to rail freight customers.

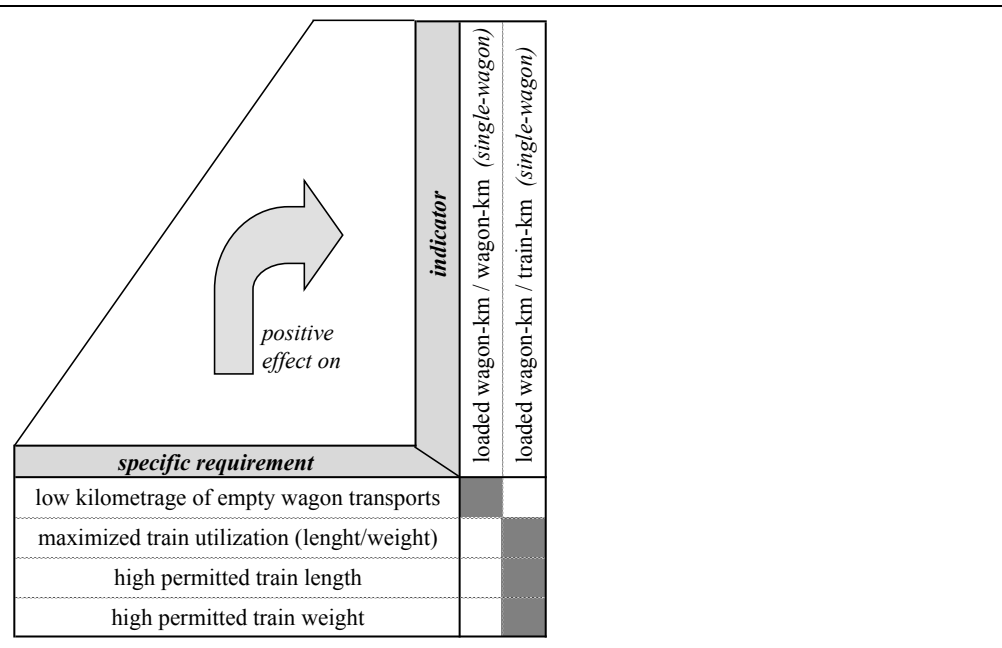
### 5.2.2.2 Requirements for High Effectiveness at Freight Railways

Measuring the effectiveness at freight railways is only relevant for single wagonload services, which offers a regular train schedule to customers<sup>24</sup>. The proposed indicators are *loaded wagon-km per wagon-km* and *loaded wagon-km per train-km*. The first indicator depends on the kilometrage of empty wagon transports. This should be as low as possible. The essential requirement for the second indicator is to have maximized train utilisation

<sup>24</sup> For details please refer to Appendix B.

rates with loaded freight wagons. The possibility to operate long and heavy trains further improves this indicator.

**Figure 5-4: Requirements for high effectiveness at freight railways**



### 5.2.2.3 Requirements for Low Unit Costs and High Earning Power at Freight Railways

Unit costs of main line locomotives, shunting locomotives, and freight wagons highly depend on their procurement costs, leading to yearly depreciations in bookkeeping. A possible alternative is their leasing. Both leasing and depreciation costs should be as low as possible for low unit costs. The second important cost driver of rolling stock is maintenance. High technical reliability and maintainability, as well as efficient maintenance structures can lower maintenance and thus unit costs.

Train driver and shunter costs mainly depend on salary and ancillary labour costs, respectively on the leasing rates, if they are temporarily hired from a third party. The reduction of these factors consequently lower unit costs for personnel<sup>25</sup>.

Low track access charges and low fees for changed train paths minimize the indicator *train-path costs per train-km*. Train path costs are strongly influenced by the general pricing level but also to which extent freight railways assign their transports on low cost train-paths<sup>26</sup>. Freight railways also dispose of options to minimize their train-path

<sup>25</sup> Collective employment agreements and legal restrictions set tight limits in practice. Besides, salary reductions would have a strongly negative effect on the motivation of employees and their loyalty to the company. Reducing unit costs of personnel is therefore often not a feasible option.

<sup>26</sup> This possibility is limited with today's track access charging system of Switzerland [WEIDMANN ET AL. (2007)]. This will change with new system valid from 2013, which includes time- and section-related price differentiations [SBB (2012)].

changing fees. The simplest way is to not even let them occur. If that is not possible, unneeded train paths should be cancelled as early as possible as accruing cancellation fees are time-dependent [SBB (2010-1)].

**Figure 5-5: Requirements for low unit costs and high earning power**

<i>specific requirement</i>	<i>indicator</i>	locomotive costs / main line locomotive	train driver costs / train driver	freight wagon costs / freight wagon	shunter costs / shunter	shunting locomotive costs / shunting locomotive	train path costs / train-km	revenue / loaded wagon-km ( <i>single-wagon</i> )	revenue / train-km ( <i>block trains</i> )
low maintenance costs (locomotives)		■							
low depreciation/leasing costs				■					
low maintenance costs (wagons)						■			
low salary/leasing costs			■						
low ancillary labour costs					■				
low fees for changed train paths							■		
low track access charges								■	
numerous unique selling points									■

Eventually freight railways can only enforce high transport prices without losing transport volumes, if they dispose of numerous unique selling points<sup>27</sup>. This maximizes earning power and leads to high *revenue per loaded wagon-km* and *revenue per train-km*.

### 5.2.3 Summary

The identified specific requirements for high productivity at freight railways can be clustered to six general ones (Figure 5-6). The first two general requirements are a *long and stable planning horizon* and *steady total traffic volumes*. This enables dense schedules with low numbers of unproductive transfers and the maximization of train utilisation. A long and stable planning horizon furthermore reduces the number of train-path cancellations and enables a future-oriented maintenance planning to ensure high availability of personnel, locomotives and freight wagons in times of high demand.

<sup>27</sup> A low competition would principally have a similar effect.

**Figure 5-6: Requirements for high productivity at freight railways**

<i>specific</i>		<i>generalised</i>	
1	dense schedules for main line locomotives	steady total traffic volumes	long and stable planning horizon
2	few and short locomotive transfers		
3	dense schedules for train drivers		
4	few and short train driver transfers		
5	dense schedules for shunting locomotives		
6	dense schedules for shunters		
7	maximized train utilization (length/weight)		
8	low fees for changed train paths		
9	demand-oriented availability of locomotives		
10	demand-oriented availability of wagons		
11	demand-oriented availability of personnel		
12	short idle time of freight wagons at customer	lean transport network with standardised services	
13	low kilometrage of empty wagon transports		
14	long transport distance		
15	high rate of booked freight wagons		
16	no multiple unit trainsets		
17	few delivery points per route		
18	short delivery distance per route		
19	numerous freight wagons per delivery		
20	high transport speed	appropriate rail infrastructure	
21	low track access charges		
22	high permitted train length		
23	high permitted train weight		
24	low maintenance costs	low fixed costs of production units	
25	low depreciation/leasing costs		
26	low salary/leasing costs		
27	low ancillary labour costs		
28	numerous unique selling points	high transport revenue	

The third general requirement is a *lean transport network with standardised services*. It subsumes a number of specific requirements such as high rates of booked wagons, low kilometrages of empty wagon transports, or the possibility to operate trains at long distances. High rail freight productivity further requires an *appropriate rail infrastructure*, which allows the operation of long and heavy trains at high speed. The last two general requirements for high productivity at freight railways are termed as *low fixed costs of production units* and *high transport revenues*. They comprise a number of specific requirements such as low maintenance costs, low leasing costs, and the necessity of numerous unique selling points.

## 5.3 Evaluation of Operational Processes

### 5.3.1 Approach

Derived requirements for high productivity in chapter 5.2 will be used in the following to evaluate the relevancy of the identified operational processes in chapter 5.1 with regards

to productivity. The most relevant ones are then selected for more detailed empirical analyses (chapter 6).

Each process will be qualitatively classified according to their influence on the individual requirements for high productivity. The possible categories are “not existing” (0), “limited” (1), and “significant” (2).

A process with a “significant” influence on a productivity requirement must fulfil two criteria. First, people being responsible for this process must dispose of a high level of freedom for decision-making. That means, they have only few binding guidelines from superior processes to fulfil their tasks. This is an essential prerequisite for being able to improve productivity actively. A high level of freedom of decision-making is not sufficient though. It must be coupled with a high effect on productivity. Although this effect is difficult to define in a generic sense, there are several indicators helping to make a reliable estimation. For instance, the effect of a certain process generally correlates with the number of affected rolling stock and personnel. If nearly all assets are affected, even small individual productivity improvements may cause a high overall effect. Another approach is the comparative evaluation with other processes. A high effect of a process is regarded as given, if its output has a dominating significance for a productivity requirement, while other processes are comparatively negligible.

If a process has no effect on a certain productivity requirement and/or no level of freedom for decision-making, its influence is declared as “not existing”. As a logical consequence, the influence of a process is classified as “limited” if it neither fulfils the above criteria for a “significant” or “not existing” influence. Such processes are characterised by an existing level of freedom for decision-making, but quite restricted by superior process guidelines or binding input data. They furthermore have no dominant effect on a certain productivity requirement.

After having classified the influence of each process on the individual productivity requirements, the associated numerical values are summed up. This allows a quantitative ranking, showing the most relevant processes for productivity (Table 5-1).

## **5.3.2 Discussion**

### **5.3.2.1 Short-term Timetable Planning**

The main task of short-term timetable planning is elaborating timetables for short-term block train services. This requires a high degree of freedom for decision-making, as shipment orders generally arrive one week in advance only (chapter 2.1.2.3). For that, they must dispose of a sufficient number of available locomotives and train drivers. Further it is necessary that incoming weekly block train orders have certain flexibility in terms of time. Otherwise, train-path conflicts of overlapping transports would be unsolvable. This also gives planners the flexibility to provide the grounds for creating optimal train locomotive and train driver tours later on. The influence of short-term

timetable planning on the schedule density of main line locomotives (1)<sup>28</sup> and train drivers (3) is therefore classified as significant.

Further, timetable planners may coordinate departure/arrival times of trains to reduce unproductive locomotive and train driver transfers (2) (4). The influence of short-term timetable planning on this productivity requirement will be limited overall, as it requires the existence of suitable follow-up transports. Besides, locomotive transfers constitute a small percentage of locomotive performance only. At SBB Cargo, this share is at around 1.3% [SBB (2010-2)].

Short-term timetable planning is also responsible for booking yet missing train paths. Depending on the requested time and itinerary of train paths, transport time may differ. Short-term timetable planning therefore has a (limited) influence on the transport speed of trains (20). The management of train-paths does also affect the level of generated fees for changed train paths (8). The later train-paths are cancelled, the more it costs [SBB (2010-1)]. However, fees for train-path cancellations are constant between 30 days and 1 day prior to usage. This limits the possibilities for short-term timetable planning to reduce track-changing fees through early train-path cancellations. Alternatively, short-term timetable planning can avoid cancellation fees by using train-paths of cancelled trains for other ones. This requires the availability of suitable transports in terms of time and itinerary, which is expectedly often not given however.

Eventually, short-term timetable planning may also help maximize train utilisations (7) of single wagonload trains. An example would be the cancellation of one (from several) underutilized trains on certain relations. As timetable adjustments in single wagonload must respect a number of restrictions (e.g. connecting trains), short-term timetable planning will expectedly have limited freedom of decision-making only.

### **5.3.2.2 Leasing of Rolling-Stock and Personnel**

The process of leasing rolling stock and personnel has a significant influence on several productivity requirements. Provided that information about future transport demand is timely available, this process can actively increase the number of available main line locomotives (9), freight wagons (10), and personnel (11) at times of high demand, while decreasing it at times of low demand. Ensuring a demand-oriented availability of rolling stock and personnel is further a fundamental requirement for efficient deployment planning. Dense schedules are only possible if the number of rolling stock and personnel is in line with actual demand. The freedom of action for people leasing rolling stock and personnel depends on given company regulations. Within these limits, they will enjoy a high degree of freedom for decision-making, as leasing decisions are generally based on uncertain information of future transport demand. This requires flexible structures for decision-making to elaborate, evaluate and implement appropriate leasing strategies.

---

<sup>28</sup> The numbers in parentheses indicate the specific requirements in Figure 5-6.



### 5.3.2.3 Preventive Maintenance Planning (locomotives)

On the operational level, preventive maintenance planning determines the time slots for locomotives with due preventive maintenances in repair shops. If maintenance stops are planned in existing idle times or at days of low transport demand, this process contributes to dense schedules of main line locomotives (1) and shunting locomotives (5). Notably small maintenances lasting few hours only qualify for this measure. As depicted earlier in this study, small maintenances are due approximately every 10'000 km. Assuming an annual kilometrage of 100'000 km, around 20% of all main line locomotives require a small maintenance each week.

Preventive maintenance planning can further help reduce the distance of unproductive locomotive transfers (2), if due locomotives are consistently sent to nearby repair shops. At last, preventive maintenance planning also influences the availability of locomotives (9). Technical failures may be the consequence, if due maintenances are not planned in time.

Generally however, preventive maintenance planning has a limited freedom for decision-making to improve productivity of locomotives. The approximate due dates for planning maintenances are given by superior time- or distance dependant maintenance plans. Besides, limited maintenance capacities at repair shops and the need of balanced maintenance volumes set tight boundaries as well.

### 5.3.2.4 Planning of Vacation, Overtime, and Time off in Lieu

Planning of vacation, overtime, and time off in lieu for train drivers and shunters has a comparable effect on productivity as preventive maintenance planning has for locomotives. It allows adapting the available number of employees to actual demand. It is assumed that vacations of employees are generally determined earlier than two months in advance. Vacation planning might consider common seasonality in transport demand but is not able to influence the available number of employees in daily business. In turn, planning of overtime and time of in lieu allows adjusting the available number and working hours of employees even at short-notice. In Switzerland, this effect is considered as significant, although working time of shift workers is regulated in detail. This illustrates the following examples: First, the balance of working hours of a train driver at SBB Cargo may vary between +150/-40 hours during the year and between +75/-30 hours at the end of year<sup>29</sup>. Second, the current collective labour agreement of SBB Cargo allows working shifts of up to 14 hours in exceptional cases [SBB CARGO (2010)]<sup>30</sup>. This is an increase of 27% compared to the generally allowed maximum of 11 hours. Third and last, employees at SBB Cargo are entitled to have 115 days off each year. This makes on average of 10 days off per month, whereby only 6 days off must minimally be granted

<sup>29</sup> Vereinbarung über die bereichsspezifische Arbeitszeitregelung für das Lokpersonal der SBB Division Cargo (BAR LP), 01.09.2008

<sup>30</sup> A working shift at SBB Cargo comprises working time and pauses.

each calendar month. All these regulations give room for adjusting the available number and performance of train drivers and shunters according to actual demand.

The process of planning vacation, overtime, and time off in lieu also determines the boundary conditions for subsequent processes like deployment planning. It is not possible to create dense schedules overall, if there are too many employees available. An adapted planning of overtime and time off in lieu to actual transport demand therefore provides the grounds for dense schedules for train drivers (3) and shunters (6).

### **5.3.2.5 Distribution Planning of Empty Wagons**

Distribution planning of empty wagons is a highly complex optimisation task, which is performed with support of IT-Systems in Switzerland (chapter 5.1). Algorithms determine, which empty freight wagons are sent to which destinations of demand and on which itinerary. The conception of these algorithms has a decisive effect on the kilometrage of empty wagon transports. On the operational level however, there is little room for decision-making. Manual modifications of calculated empty wagon distributions can only be the exception. Otherwise, algorithms would have to be improved. People responsible for planning distributions of empty wagons do nevertheless dispose of measures for improving productivity at freight railways. Not all types of freight wagons will constantly show a high booking rate, requiring shortest possible wagon cycles. This gives room for flexibility in planning. For such underutilized types of wagons, distribution planning of empty wagons could bring forward early known wagon orders to fill up trains with low utilisation-rates, for instance. This measure could make additional trains avoidable at peak times, which improves the overall utilisation rate of trains (7). Yet, many other constraints will have to be considered before cancelling a regularly scheduled train, which is why the effect is regarded as limited.

Distribution planning of empty wagons could also improve productivity of highly demanded freight wagons. Thanks to its information about current position of freight wagons, planners of empty wagon distributions should be able to identify unusual long idle times of freight wagons at customers. Notably highly demanded types of freight wagons must be given free for new deployments, as soon as they are unloaded at customers. An active intervention at customers could help shorten idle times of freight wagons at customers (12). This measure increases the available number of freight wagons in case of empty wagon shortages. This will usually affect a minor part of freight wagons only, which is why the effect on productivity is rather limited overall. Despite, the freedom of decision-making for implementing this measure could also be restricted by demurrage contracts with shippers, allowing them to use freight wagons as short-term interim storages.

### **5.3.2.6 Corrective Maintenance Planning**

Corrective maintenance planning will have little influence on productivity only, as far as it concerns locomotives. For one, breakdowns or safety-relevant failures require an

immediate take out of service and repair, leaving no room for planning. For another, non-safety relevant failures can be fixed during one of the frequent preventive maintenances. Again, this leaves no room for planning.

The situation is different for freight wagons. Preventive maintenances are much less frequent, which makes synergy effects with corrective maintenances less likely. In addition, there are many types of freight wagons with differing demand behaviours. A high technical availability is therefore not equally important for all freight wagon types. Provided having information about future demand, corrective maintenance planning can prioritise necessary repairs of freight wagon types with high demands at cost of freight wagons with low demands. This helps achieve a demand-oriented availability of freight wagons (10). However the overall effect strongly depends on further factors, such as the average age of freight wagons and lead times in repair shops.

Damaged freight wagons can also be used for balancing train utilisation in single wagonload traffic. As there is no customer order behind, such wagons require no immediate shipment. This gives corrective maintenance planning the possibility to ship damaged wagons specifically on low utilized trains. This approach can make additional trains avoidable at peak times, which improves the overall utilisation rate of trains (7).

### **5.3.2.7 Deployment Planning of Locomotives and Personnel**

The basic procedure in deployment planning of locomotives, train drivers, and shunters is comparable and therefore discussed together. The two major tasks in deployment planning are duty scheduling and rostering. Similar to distribution planning of empty wagons, duty scheduling is a complex optimisation task with many regulations to be considered. Computer-based optimisations tools appear highly useful, but are still not common practice [CLAUSEN AND BAUDACH (2008)]. This study therefore assumes that optimisations at duty scheduling is done manually<sup>31</sup>. In this case, duty scheduling has a significant effect on the schedule density of main line locomotives (1), shunting locomotives (5), train drivers (3), and shunters (6). It has principally the power to create schedules, which are as close as possible to the theoretical optimum. However, it cannot influence the theoretical optimum itself. This is largely determined by the basic structure of the timetable and the flexible availability of assets, which superior processes and regulations are responsible for.

An important effect is noticeable, regarding the room for improvement at duty scheduling. The better they reach the optimum, the less becomes their room for improvement in a long-term perspective. This is because optimal duty scheduling allows superior processes to reduce the number of locomotives, freight wagons, or personnel. This creates a real

---

<sup>31</sup> The use of mathematical optimisation algorithms in deployment planning would shift the influencing possibilities in deployment planning from the operational to the strategic level, in which the conception of the algorithms is elaborated. The room for decision-making in the operational deployment planning would therefore become negligible and would limit to asset rostering.

productivity gain. At the same time, it narrows the room of manoeuvre for duty scheduling to improve productivity. In a well-rehearsed planning system, duty scheduling should only have little room left for improvement. Further optimisations are only possible with the implementation of new (mathematical) techniques. The influence of duty scheduling on the density of schedules is therefore classified as limited.

The rostering of personnel and locomotives – the second major task in deployment planning – will eventually have a negligible effect on the requirements for high productivity only. Predefined duty schedules and regulations largely determine the output of this sub-process.

### **5.3.3 Summary**

Table 5-1 summarises the above discussions in form of an influence matrix. It allows the following three general conclusions:

- Operational processes can influence 14 out of the 28 identified requirements for high productivity. They therefore play an important – but not exclusive – role for achieving high productivity at freight railways. A “productivity-friendly” environment is equally important. This includes, for example, a lean transport network and appropriate rail infrastructures, which are determined by strategic processes or by external decision-makers.
- The three most important requirements, which operational processes can influence, are the schedule density of locomotives, the schedule density of train drivers, and the demand-oriented availability of personnel (train drivers/shunters). Operational processes are further well able to minimize locomotive transfers, to maximize train utilisation, and ensure a demand-oriented availability of locomotives and wagons. All of these requirements belong to the general productivity categories “long and stable planning horizon” and “steady transport volume” (Figure 5-6).
- The matrix further shows that short-term timetable planning and the leasing of rolling stock and personnel are the most relevant operational planning processes for improving productivity. In turn, deployment planning and corrective maintenance planning comparably have little influence on productivity of freight railways.

**Table 5-1: Process influence matrix**

		Ranking
1	short-term timetable planning	9
2	leasing of rolling-stock and personnel	6
3	preventive maintenance planning (locomotives)	4
4	planning of vacation, overtime, and toil*	4
5	distribution planning of empty wagons	3
6	corrective maintenance planning	2
7	deployment planning of locomotives	2
8	deployment planning of train drivers	2
9	deployment planning of shunting locomotives	1
10	deployment planning of shunters	1

operational planning processes	influence
dense schedules for main line locomotives	2
few and short locomotive transfers	1
dense schedules for train drivers	2
few and short train driver transfers	1
dense schedules for shunting locomotives	2
few and short train driver transfers	1
dense schedules for shunting locomotives	2
dense schedules for shunters	2
maximized train utilization (length/weight)	1
low fees for changed train paths	1
demand-oriented availability of locomotives	0
demand-oriented availability of wagons	2
demand-oriented availability of personnel	0
short idle time of freight wagons at customer	0
low kilometrage of empty wagon transports	0
high transport speed	1
low maintenance costs	0
low depreciation/leasing costs	0
low salary/leasing costs	0
low ancillary labour costs	0
long transport distance	0
high rate of booked freight wagons	0
no multiple unit transets	0
few delivery points per route	0
short delivery distance per route	0
numerous freight wagons per delivery	0
low track access charges	0
high permitted train length	0
high permitted train weight	0
numerous unique selling points	0

0 = no influence  
 1 = limited influence  
 2 = significant influence

\* time off in lieu

# 6 Analysis of Relevant Freight Rail Processes for Productivity

---

## 6.1 Introduction

Chapter 5 identified and evaluated operational planning processes at freight railways on a generic level. The following detailed analysis now focuses on the five most important processes, listed in Table 5-1. These are short-term timetable planning, leasing of rolling-stock and personnel, preventive maintenance planning (locomotives), planning of vacation, overtime and time of in lieu, and distribution planning of empty wagons.

The individual tasks as well as their temporal sequence of these processes are disclosed empirically on the example of SBB Cargo, the major freight railway in Switzerland. For that face-to-face interviews have been conducted with people being responsible for these processes at SBB Cargo during 2010 and 2011. All processes are depicted with the modelling method BPMN<sup>32</sup>.

Based on these empirical process analyses, major challenges are identified and discussed. This serves as important source for the subsequent elaboration of possible collaborative approaches with shippers and their benefit from the perspective of a freight railway.

## 6.2 Short-term Timetable Planning (Block Trains)

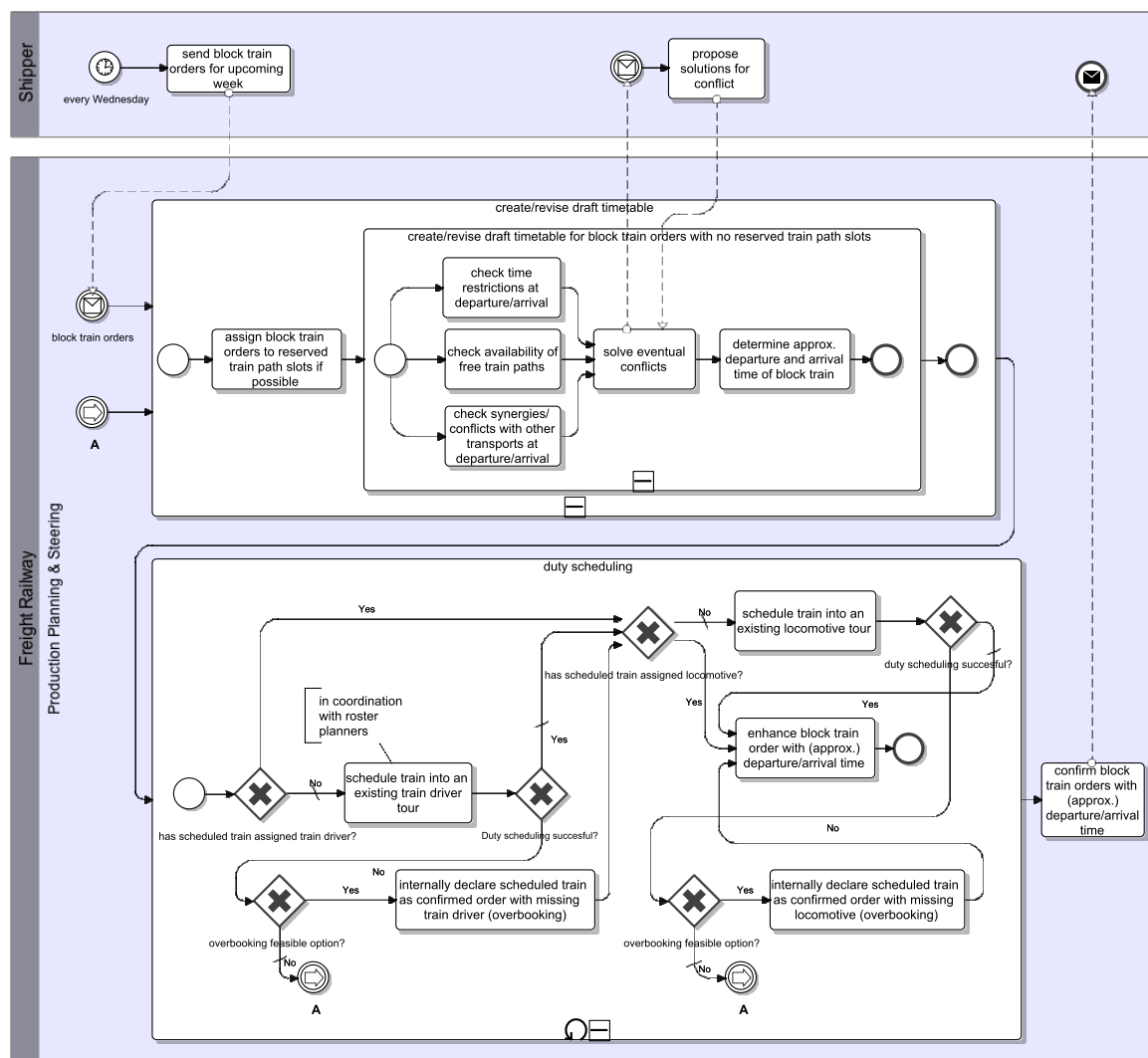
### 6.2.1 Process

Short-term timetable planning can be separated in two major parts. Figure 6-1 shows the first part of this process. It starts at mid-week with the reception of block train orders for the upcoming week and lasts around 1-2 days. The first planning task consists in the elaboration of a draft timetable, yet without considering the availability of resources like locomotives or train drivers. Parts of weekly ordered block trains are regular enough to reserve train paths on a bimonthly or even annual basis. If possible, incoming block train orders are first assigned to such existing train paths.

---

<sup>32</sup> For details about this method please refer to Appendix A.3.

Figure 6-1: Timetabling process of weekly block train orders (1/2)



In a second step, feasible timetables are created for block trains with missing train paths. Several aspects must be considered for that. First, given time restrictions for the departure/arrival of block trains have to be checked. Interviewed experts verified the assumption in chapter 5.3.2.1, that weekly block train orders must have certain flexibility in terms of time. Otherwise, train-path conflicts of overlapping transport orders would be unsolvable. Second, the availability of free train paths has to be checked. This is often done by experience. Third and last, eventual synergies or conflicts with other transports have to be considered. This is an important preliminary for creating optimal duty schedules for train drivers and locomotives later on. Eventual conflicts, optimisation potentials and detected planning errors must then be approached together with the respective shippers. After that, approximate departure and arrival times of trains can be determined<sup>33</sup>.

<sup>33</sup> Note that exact departure/arrival times can only be indicated after having firmly reserved associated train paths.

Duty scheduling of locomotives and train drivers is part of the timetabling process for weekly block trains at the analysed freight railway. As assumed in chapter 5.3.2.7, this task is done without support of mathematical optimisation tools. If a block train order is scheduled on an already reserved train path, a train driver and/or locomotive duty might already be assigned to. Otherwise, the block train order has to be planned into an existing train driver and locomotive tour. Duty scheduling for weekly ordered block trains usually have a number of specifically dedicated tours at disposal. Otherwise, the granted flexibility and service quality would not be achievable.

There are three options if duty scheduling is unsuccessful. The first – most common – option is to revise the initial draft timetable to solve this conflict in duty scheduling. The second option is to declare a specific train as confirmed but with no assigned train driver and/or locomotive resources (“overbooking”). This approach is only feasible if there is a significant chance of other train cancellations until the foreseen date of transport. This measure requires a sound experience and carries the risk of not being able to ship certain block trains at confirmed times. The third and ultimate option is the rejection of certain block train orders. This first part of short-term timetable planning is eventually completed with the confirmation of submitted block train orders to shippers, indicating (approximate) departure and arrival times of trains.

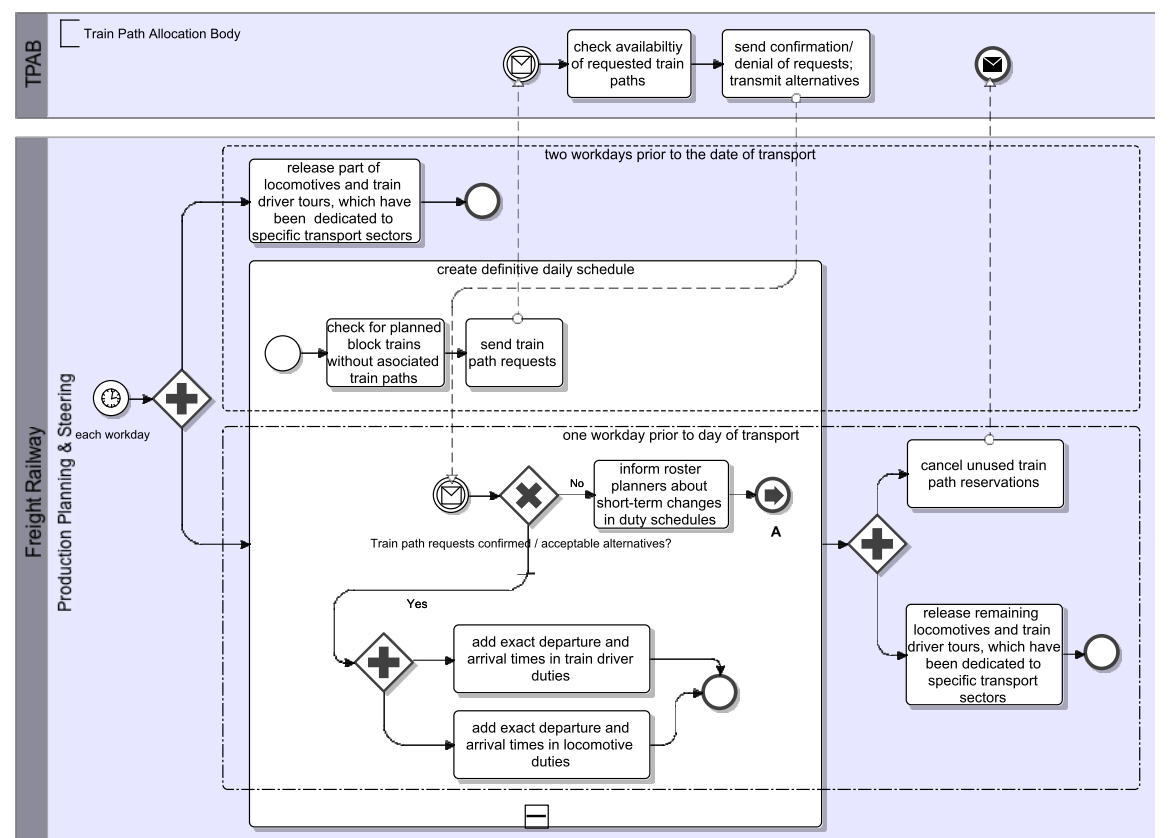
The second part of the short-term timetabling process of weekly block train orders is performed on a daily basis (Figure 6-2). This detail planning starts two workdays before the date of transport. First, the majority of locomotive and train driver tours, which have been dedicated to specific transport sectors, are released to other transports as well. Second, requests for missing train paths are sent to the train path allocation body (TPAB). The freight railway receives the confirmation together with exact departure/arrival times the following day. In case of unavailability, TPAB proposes an alternative train path. A revision of the foreseen timetable is necessary, if the requested train path is unavailable and the proposed alternative no feasible option. In this case, roster planners for train drivers must be informed immediately. If the train path request is confirmed, the planned train driver and locomotive duties are fine adjusted according to the exact times of the reserved train paths.

The definite schedule is thus latest completed one workday prior to the date of transport. In the following, unused train path reservations are cancelled at TPAB and the remaining locomotive and train driver tours, which have been dedicated to specific transport sectors, are released to any transports.

Beside this standard process for timetabling weekly block train orders, subsequent changes and extra orders are everyday occurrences. The handling of such individual customer requests basically follows the same procedure as for the regular weekly orders.



Figure 6-2: Timetabling process of weekly block train orders (2/2)



## 6.2.2 Discussion

Shipper information is of essential importance in short-term timetable planning of block trains, as it entirely relies on incoming weekly shipment orders. Some shippers additionally provide shipment forecasts as well. However, they only cover a minor part of total traffic at the analysed freight railway<sup>34</sup>. These forecasts are therefore neither suited to determine traffic peaks nor to elaborate detailed timetables, as subsequent incoming shipment orders could make major re-planning necessary. Forecasts are therefore not used in this process yet<sup>35</sup>.

As a result, imminent traffic peaks are actually unknown for planners until shipping companies have submitted the majority of weekly block train orders for the upcoming week. Responsible planners at freight railway thus neither have enough time nor options – other than denying orders – to level traffic peaks, once identified.

Denying block train orders should always be the last resort. For one, shippers expect the fulfilment of placed orders. Demanding a re-planning on shipper's side is furthermore difficult, as shippers have largely finished their transport planning at this stage (otherwise they were not able to place shipment orders). Besides, it would also contradict the quality

<sup>34</sup> For more details please refer to chapter 8.

<sup>35</sup> Exceptions are forecasts about transport demands at public holidays and planned production shutdowns.

standard of the freight railway. For another, cancelling a block train order is a significant loss of revenue for the freight railway. The consequence is notably unfortunate, if it later turns out that the train could still have been operated.

The freight railway is therefore generally obliged to schedule incoming block train orders on the requested dates. Sufficient production capacities have to be at disposal for nearly any possible demand. Concurrently however, production capacities should be as low as possible to ensure acceptable productivity. Hence, insufficient locomotive and/or train driver capacities can occur during times of peak demand. In this situation, the only option – besides denying block train orders – is to overbook production capacities and trust on subsequent train cancellations. This decision largely relies on experience and carries the risk, that certain block trains cannot be operated on the confirmed time or day. Ensuring high quality standards with limited production capacities is therefore a risky challenge for planners at the freight railway.

Missing comprehensive shipment forecasts and the short-term placement of shipment orders creates another challenge for freight railways. The elaboration of optimal duty schedules is difficult to realise within the short time given and with no support of mathematical optimisation tools. The optimisation of locomotive and train driver duties thus remains superficial and focused on individual transport planning segments (e.g. mineral oil). The situation is further exacerbated by the fact, that certain transport sectors dispose of some exclusive locomotives and train driver tours for planning. This is necessary to maintain planning flexibility for sectors with train orders at very short notice. However, their late release for other transports makes a cross-sectoral optimisation difficult.

## **6.2.3 Collaborative Approaches**

### **6.2.3.1 Using Shipment Forecasts for Joint Levelling Traffic Peaks**

The early information about planned future block train shipments would help freight railways identify traffic peaks at a time, where transport planning at shippers is not finished yet. Shifting certain block trains in close cooperation with shippers could help level days with peak demand. This allows a reduction of reserve capacities, which increases average schedule density of train drives and locomotives.

Prediction errors would be acceptable to a certain extent, as they are used for identifying (exceptional) peaks and not for detailed planning. The lower limit of acceptable forecast accuracies are in the range 80%, according to interviewed experts. A major requirement of this approach is a high share of forecasted traffic volumes at the freight railway. This is necessary for gaining a comprehensive picture about expected traffic for specific days. Interviewed planners indicated a necessary percentage of at least 75% for an independently planned transport sector (e.g. mineral oil) to make a reliable statement.

This collaborative approach will lead to an increased planning effort on both freight railway and shipper side. It further needs the cooperativeness from shippers to adjust initial transport planning. These factors increase the risk of opposition from shippers.

### **6.2.3.2 Using Shipment Forecasts for Optimising Timetables and Duty Schedules**

Earlier information about future block train orders would give planners more time to elaborate more efficient timetables and duty schedules for locomotives and train drives. In addition, unused time slots of locomotive and train drivers, dedicated to specific transport-sectors, could be released earlier. This approach requires a significantly higher forecast accuracy than for levelling traffic peaks. This is because few subsequent changes of forecasted shipments can already make initial duty scheduling obsolete, as optimized connections within locomotive and train driver tours would not match anymore. Time-consuming subsequent rescheduling cycles could be the consequence, ruining the benefit of having early shipment information.

Evidently, the earlier forecasts are available for short-term timetabling, the better. However, the requirement of having forecasts from most shippers in combination with an acceptable accuracy set tight limits in practice. Interestingly, the interviewed experts even regard a forecasted time horizon of two weeks as already useful for levelling certain peaks and optimize duty schedules.

Provided that the minimal requirements on needed shipper information are given, neither additional planning efforts nor investment costs are generated. If shippers are capable of providing accurate forecasts, they must evidently have started planning already. Opposition against this form of collaboration is therefore unlikely.

### **6.2.3.3 Placing Shipment Orders with Flexible Due Dates**

Optimising timetables and duty schedules requires some degree of flexibility, either on freight railway or on shipper side. In this regard, even a small proportion of shipment orders with flexible shipment due dates would be highly advantageous from the freight railway's perspective. Planners at freight railways could use such flexible shipments to balance shipping volumes over the week and to reduce idle times of locomotives and train drivers.

However, most shippers using block train services provide and plan their own freight wagons. Allowing the freight railway to determine actual shipment dates would therefore strongly interfere shippers' efforts to create optimal freight wagon schedules. Strong opposition against this measure is thus expected and a significant discount would have to be granted to compensate suboptimal freight wagon schedules at shippers. In any case, flexible shipment due dates are only a feasible option if freight wagons of shippers are not fully utilised and thus flexibly deployable. However, this will not be usual practice at

shippers, as underutilized freight wagons are associated with extra costs. The feasibility of shipment orders with flexible due dates is therefore very questionable.

#### **6.2.3.4 Taking Charge of Shipper's Freight Wagon Scheduling**

Customers of block train services mostly use their own freight wagons and plan their deployment in form of fixed train compositions. The elaboration of optimal turnaround schedules for train compositions is therefore an important planning task for those shippers. This sets tight limits for subsequent planning activities at the freight railway. Any changes of already placed shipment orders would most likely deteriorate the turnaround schedule of shippers' train compositions.

There are therefore several advantages if freight railways provide and schedule train compositions for all their customers. The larger the transport volume in certain geographical area and transport sector is, the higher is the probability for synergy effects when planning train compositions together. For example, it simplifies the search of alternative deployments for train compositions, whose original deployments have been cancelled at short-notice. The increased overall utilisation level of freight wagons reduces the number of needed freight wagons and thus freight wagon costs.

Another advantage is the simplified shift of dates of consignment to level peak demands. Notably small shippers with few train compositions have little flexibility to change dates of consignment, as other planned transports with this train composition would be affected otherwise. If a freight railway owns and schedules all train compositions for a certain transport sector, a rescheduling is easier to perform due to the higher number available. This approach would eventually also allow freight railways to accept a decreased utilisation rate of train compositions if a higher utilisation level for locomotives and train drivers is achieved in turn.

Taking charge of shipper's freight wagon scheduling denotes a major change in the tasks and responsibilities between shippers and freight railway. It presupposes the confidence on shipper's side that the freight railway is able to schedule train compositions more efficiently and cost-effective than if they continue doing it by themselves. An intensive, daily collaboration would be necessary during the phase of transport planning to adjust shippers transport demand with an optimal overall schedule for train compositions. There is a risk that shippers are not willing to give up control of scheduling block train compositions as they might fear insufficient productivity gains and deteriorated service levels.

Although the participation of a minority of shippers already helps optimize schedules for locomotives, train drivers, and freight wagons, the benefit of this approach increases progressively with the number of participants. Furthermore, detailed and highly accurate forecasts are necessary, as this information is needed to schedule assets in detail. Too many subsequent changes could make initial planning obsolete, leading to inefficient and costly re-planning efforts.

### 6.2.3.5 Publishing Unused Shipment Time Slots for Block Trains

The freight railway could inform shippers about available time slots on specific relations. If shippers consider this information for placing their shipment orders, timetables and thus duty schedules of locomotives and train drivers would become denser and thus more efficient.

The actual productivity gain will be little though for several reasons. First, the chance that a shipper has due shipments for a given date, and time is rather low. Financial incentives will therefore have to be offered so that shippers are willing to postpone or to bring forward their planned shipments. Second, unused time slots cannot be offered before shipment orders from regular customers have arrived. This would endanger the service level, which has been granted to regular customers. This measure is therefore primarily focused on acquiring spot traffics, limiting the overall potential. Third and last, underlying train paths are always linked to a certain relation. Unused time slots will therefore most likely find interested parties on highly demanded relations only. This further limits the potential of this approach.

On the other side, additional costs are generated for the freight railway. Unused time slots will have to be updated and published continuously. Further, offering unused time slots to shippers is not trivial. Keeping certain time slots in reserve enables key customers placing extra orders at very short-notice. This is an important selling argument, which must be weighted up with the possible productivity gain of offering unused time slots to anyone.

In sum, the potential productivity gain is regarded as too little compared to the additional effort being necessary at the freight railway. This measure is therefore not recommended to be pursued.

## 6.3 Short-term Timetable Planning (Single Wagonload)

### 6.3.1 Process

There is no regular process for adjusting single wagonload timetables on a weekly or even daily frequency. Timetables for the single wagonload network are planned annually and updated bimonthly if necessary. This procedure is plausible, as the single wagonload network offers a service with trains at regular intervals, offering shippers high transport flexibility and planning reliability. Cancelling underutilized trains, e.g. on a weekly basis, would contradict this supply-oriented concept. As shipment orders are accepted nearly at any time and in any quantities, the planning philosophy of single wagonload service is actually relying on an “unlimited” capacity of trains in Switzerland<sup>36</sup>.

<sup>36</sup> This expression is adopted from analogue terms used for describing capacity management techniques at manufacturers [SCHÖNSLEBEN (2004)].

## 6.3.2 Discussion

In the current system, short-term shipper information has no relevance for timetables in single wagonload network. As shipment orders are accepted nearly at any time and in any quantities today, an effective capacity management of trains is virtually impossible. As a consequence, the number of planned trains must cover nearly any traffic demand. This creates overcapacities at times of low demand, which reduces the effectiveness of deployed locomotives and train drivers.

Further, certain trains may have to be cancelled or enforced on a very short-term basis (usually on the same day). This can be caused by a complete lack of wagons on a scheduled train or – in contrary – a massive overflow. Today, this information is unknown until shortly before the departure of trains when all shipment orders are placed.

## 6.3.3 Collaborative Approaches

### 6.3.3.1 Capacity Planning of Single Wagonload Trains

Earlier shipment orders and bookings of empty wagons would enable changing the planning philosophy from an “unlimited” to a “limited” train capacity. There are several advantageous from a productivity perspective.

First, the number of trains in the single wagonload network could be reduced, if shippers (voluntarily or involuntarily) increase bookings in off-peak periods. The main benefit is a higher average train utilisation, which increases the effectiveness in single wagonload service. Time- and capacity-dependant transport rates would have to be implemented as incentive. The dynamic calculation of transport rates requires fix shipment orders, rather than (non-binding) forecasts. This system also demands that all shippers using single wagonload service are participating. If certain shippers were still allowed placing shipment orders whenever and as many as they want, the calculation about current train utilisation levels would become unreliable.

Second, the knowledge about current booking rates of trains could be used to implement short-term timetable planning in single wagonload service. If the booking status shows a possible overbooking of a train at an early stage, an extra train can timely be scheduled. This is a feasible option, if expected revenues justify the generated costs. Otherwise, any additional shipment requests on a fully booked train are rejected. In turn, trains showing a low booking rate could be merged with other trains.

Changing the planning philosophy from an unlimited to a limited train capacity is highly complex and needs major investments in information technologies<sup>37</sup>. It further reduces the booking flexibility of shippers and might increase shipment rates at certain periods of time. This inevitable evokes opposition at shipper’s side and entails the risk of traffic losses.

---

<sup>37</sup> No quantitative estimation was made, as its complexity would exceed the scope of this study.

### **6.3.3.2 Joint Planning of Feeder Relations with Dominant Shippers**

Relations with several daily feeder trains qualify for a new form of collaboration: The joint weekly timetable planning between the freight railway and the dominant shippers on this feeder relation<sup>38</sup>. The dominant shippers indicate the approximate number of wagons for each weekday of the following week (or more). On this basis, potentially underutilized trains are merged in a joint decision and freed-up resources can be used otherwise.

As only a limited number of trains and relations come into question for this measure, the overall benefit for productivity remains clearly limited. However, thanks to its focused approach on certain relations and shippers, the implementation risks and costs are lower too. Further, the concerned dominant shippers are not obliged to indicate exact forecasts. For estimating the possibility of merging trains, an approximate forecast of daily wagon shipments is sufficient. This will increase the chance of shippers' cooperation, despite of a certain commitment, which is associated with this approach.

## **6.4 Leasing of Rolling Stock and Personnel**

### **6.4.1 Process**

#### **6.4.1.1 Locomotives**

The analysed freight railway clearly differentiates between short-term and long-term leasing of locomotives.

Long-term leasing of locomotives is typically done on the basis of annual tenancies. This process is in the exclusive responsibility of asset management as “owner” of the locomotives. Contract partners can be other railways (both passenger and freight) or leasing providers. The process of long-term leasing is not analysed any further due to its clearly strategic character.

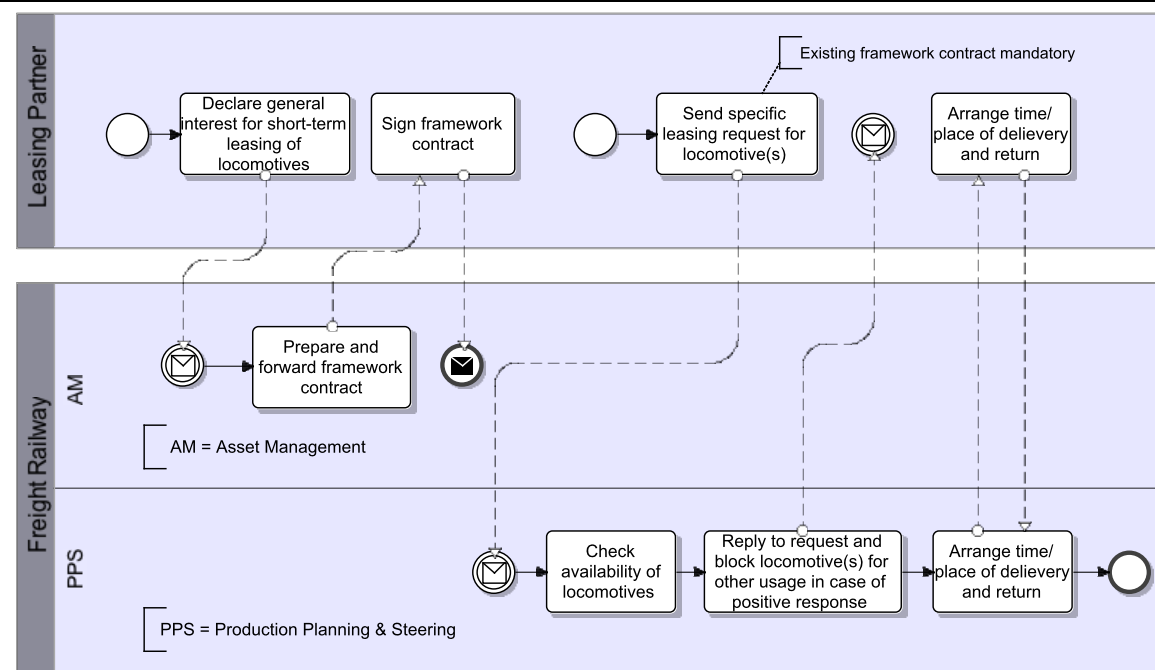
Short-term leasing of locomotives can last from a couple of hours up to one month. The process is depicted in Figure 6-3. Short-term leasing of locomotives is typically a business among railways only. At first, a framework contract has to be prepared and signed between the railway leasing the locomotive and its counterparty. After that, leasing requests for locomotives can be sent at any time by email to the leasing freight railway. The responsible unit checks the availability of locomotives and verifies that leasing requests are not contrary to own commercial interests. A response is principally possible within minutes. In case of a positive response, the requested locomotive is blocked for other usage and time/place for delivering/returning the locomotive is coordinated with the counterparty. Nearly all short-term leasing requests reach the freight railways no earlier than a few days in advance. Even leasing requests for the current day are common. This is

---

<sup>38</sup> Feeder trains connect outer nodes of the single wagonload network with a marshalling yard.

because short-term leasing requests of locomotives are normally the consequence of an unforeseeable situation such as a break down.

**Figure 6-3: Short-term leasing of locomotives**



#### 6.4.1.2 Freight Wagons

The process of leasing freight wagons is also divided in a long-term and short-term part.

Tenancies of three months and more are classified as “long-term”. Such types of leasing are again in the responsibility of asset management as the “owner” of freight wagons. The typical duration is one year or more. Depending on the freight wagon type, tenancies of less than a year can already be highly difficult to arrange.

Leasing periods of less than three months are classified as “short-term”. Such types of leasing are in the responsibility of operational planning units. In contrary to locomotives, short-term leasing of freight wagons is primarily a business between freight railways and their customers and not between railways<sup>39</sup>. The leased wagons are primarily used as short-term storage capacities in the field of track-laying and construction site traffic [SBB CARGO (2011)]. The process is analogue to the one described for locomotives in Figure 6-3. A framework contract is needed for leasing freight wagons at short-term notice. Requests for leasing freight wagons can then be sent until a few days prior to departure by email to responsible planning unit of the leasing freight railway. This unit checks the availability of requested freight wagons. In case of a positive response, concerned freight wagons are blocked for other usage and sent to the customer at the desired date.

<sup>39</sup> Until the liberalisation of the European freight rail market, short-term leasing of freight wagons was a common procedure among the European freight railways. In the meantime, these activities have largely come to a standstill.



The short-term leasing of additional freight wagons for own usage is currently no option for the analysed freight railway. Freight wagons from leasing companies are either too expensive or not available at short-notice.

### **6.4.1.3 Train Drivers**

The leasing of train drivers is no common practice at the analysed freight railway. For one, train drivers working for a freight railway have – in contrary to locomotives and freight wagons – a comparatively limited geographical operational area. For another, the permission of driving freight trains does not automatically allow driving passenger trains as well. An additional training is necessary for that. These factors limit the number of potential leasing opportunities.

Recently however, a small pool of train drivers has been established, working for both the analysed freight railway and the rail passenger division from the same group. They alternate between the two divisions every month. This gives planners of train driver rosters the possibility to adjust this planning if a lack of train drivers is looming in one division. The increased flexibility for deploying train drivers apparently justifies the additional expenses for training and coordination efforts.

Another feasible option is the short-term leasing of train drivers from leasing companies. The interviewed expert regards a leasing of train drivers within weeks or even days as possible.

## **6.4.2 Discussion**

Today's processes for the short-term leasing of locomotives and freight wagons have a rather passive character. At the analysed freight railway, rolling stock is only leased to but not from other companies. In case of incoming leasing requests from other companies, they are checked by the freight railway and confirmed in case of sufficient capacities. Notably for locomotives, leasing requests usually reach the freight railway a few days in advance only. At this time, most shipment orders have already been placed, making a reliable decision possible without further information from shippers. In case of uncertainty, the leasing request can simply be denied or its confirmation postponed. The benefit of an intensified collaboration with shippers to receive additional information about future shipments is therefore limited at current short-term leasing processes of rolling stock.

The leasing of train drivers is not yet a significant process at the analysed freight railway. However the recent establishment of a small joint train driver pool between the freight railway and the passenger rail division from the same group is regarded as highly promising approach for the future. In contrary to current short-term leasing activities for rolling stock, this collaboration requires a proactive planning. Hence the earlier future traffic volumes are known at the freight railway, the earlier additional train drivers can be organised from the joint train driver pool.

### 6.4.3 Collaborative Approaches

With the current level of short-term leasing activities and the rather passive character of leasing processes, additional information about future shipments only have little value overall. However, this would significantly change if the numbers of rolling stock and train drivers in proprietary possession were further reduced and missing resources are leased in periods of peak demand from third parties. In this case, **using shipment forecasts for leasing rolling stock and train drivers at traffic peaks** enables a demand-oriented availability of transport capacities, making deployments of locomotives, freight wagons and train drivers more efficient. This approach requires two forms of collaboration:

The first collaboration is needed with shippers to identify future peak demands. As a basic condition, a large majority of (block train) shipments must be forecasted for identifying under- and overcapacities. Today, this information is mainly unknown until one week before the date of transport (see chapter 6.2). Although leasing is principally possible until the very last day, peak demands must be known as early as possible, to increase the chance of a positive response for possibly necessary leasing requests. A negative response could have serious consequences for the service level of the freight railway. In the worst case, there are insufficient transport capacities to operate all trains. For defining an appropriate forecasting period, not only the forecasting capabilities of shippers must be taken into account but also the maximum planning period and availabilities of the leasing partner.

The second collaboration is needed with leasing partners to obtain additional rolling stock and/or train drivers if necessary. For the short-term leasing of freight wagons, large European freight railways will be the partners of first choice, as specialised leasing companies rather concentrate on the long-term leasing of freight wagons. The reactivation of this formerly common collaboration among freight railways is associated with several obstacles however. First, freight railways usually face correlating transport demands. For this reason, freight wagons will usually be over- or underutilized at the same time. Second, freight railways are potential or real competitors nowadays and the leasing must therefore not contradict commercial interests. This limits the number of possibly cooperating freight railways.

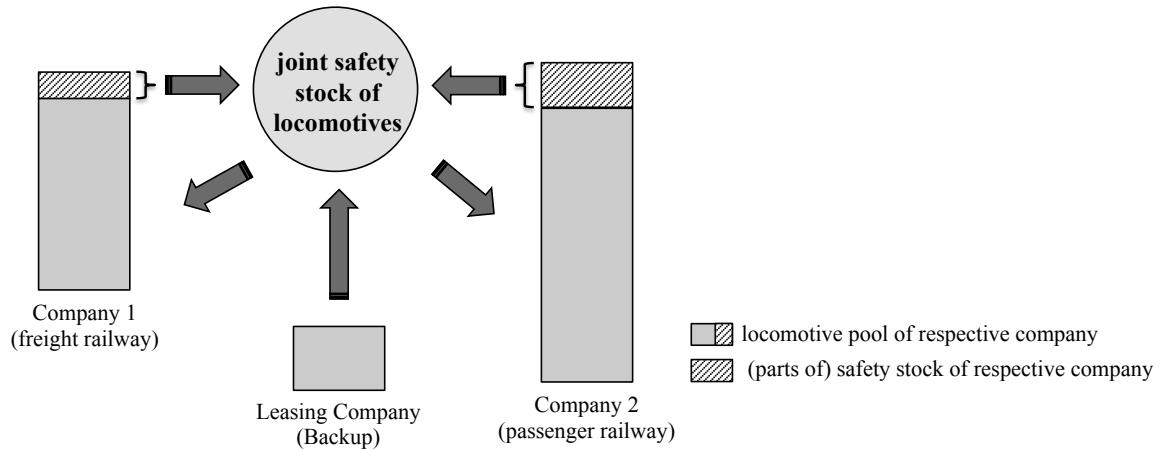
In the case of locomotives and train drivers, these problems can be avoided if the freight railway enters a leasing cooperation with a passenger railway. With regards to the leasing of locomotives, a joint safety stock is proposed, closing the gap between existing annual- and daily-based leasing activities<sup>40</sup>. In this leasing cooperation, each partner provides a number of locomotives for creating a joint safety stock of locomotives (Figure 6-4). It is backed up by a specialised leasing company to ensure the availability of locomotives even at times of overlapping peak demands. Locomotives in this joint safety stock should still

---

<sup>40</sup> This idea is inspired from the already established small joint train driver pool between the analysed freight railway and the passenger rail division in the same group (chapter 6.4.1).

be owned and maintained by the respective railways. Cooperating partners will have real-time access on trip plans of locomotives in joint safety stock and the right to book time slots of those locomotives if necessary<sup>41</sup>.

**Figure 6-4: Joint safety stock of locomotives**



Several aspects regarding this joint safety stock deserve special consideration:

First, locomotives are more and more adapted to the specific needs of transport modes, making a mutual use between freight and passenger railways increasingly difficult. For example modern freight railways generally have a maximum speed of 140 km/h, which is largely sufficient for most freight trains but not for passenger trains. In turn, many freight railways require locomotives for international deployments, which passenger locomotives are generally not designed for. In addition, there is an ongoing trend in rail passenger traffic from locomotive hauled trains to multiple units [SCI (2010)]. This further reduces the numbers of mutually deployable locomotives in freight and passenger traffic. However even this overall limited potential is considered as sufficient for the proposed joint safety stock, as it unfolds its effect even with a small number of shared locomotives.

Second, locomotives in joint safety stocks should preferably be from the same type and located in the same operational area. A large variety of locomotive type would increase training costs for train drivers, while differing operational areas make unproductive locomotive transfers necessary.

Third and last, compatible or even identical IT-Systems for planning locomotive tours make the integration less complex and costly.

The last two aspects are most likely given at railways having both a freight and passenger rail division.

<sup>41</sup> Predefined priority rules may have to be established to respect specific needs of cooperating partners.

## 6.5 Preventive Maintenance Planning (Locomotives)

### 6.5.1 Process

Locomotives require periodical preventive maintenances for ensuring high safety standards and technical reliability. There are several types of preventive maintenances, which differ in both frequency and extent of maintenance works. The required types of preventive maintenances, their sequence, and service periods are determined in maintenance plans for each locomotive. With regards to the planning horizon and responsibilities of due locomotives, this study clusters the different types of preventive maintenances in *revisions*, *large preventive maintenances*, and *small preventive maintenances*.

At intervals of several years, locomotives have to be serviced fundamentally. These so called *revisions* can last several days to weeks. Due to their complexity, revisions of locomotives need a sophisticated work preparation and capacity planning at repair shops. They are thus planned several months in advance. If at all, planning can only consider general seasonality in transport demand.

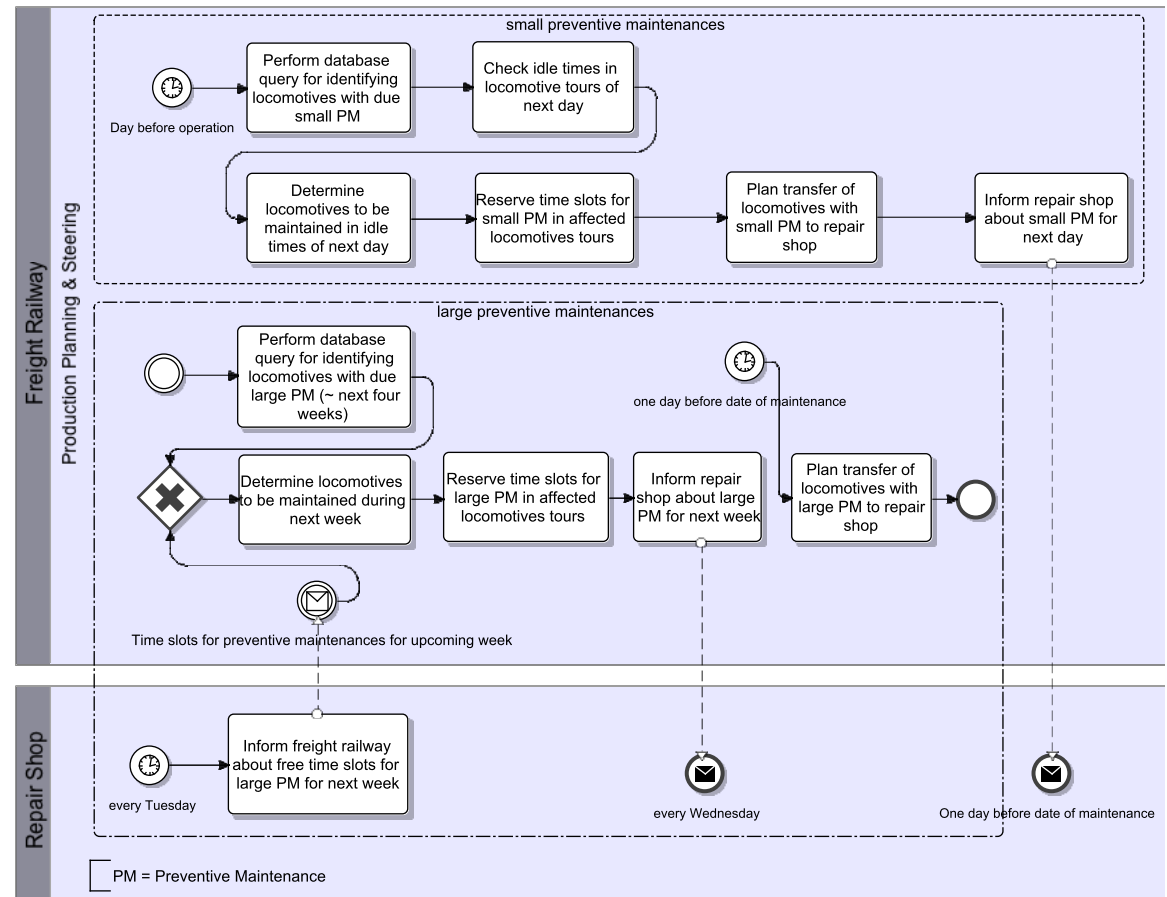
At least once a year, locomotives require a *large preventive maintenance*. The duration of this preventive maintenance work is typically between 5 and 48 hours. Figure 6-5 shows the process of planning large preventive maintenances for due main line locomotives at the analysed freight railway.

Assigned repair shops announce the available time slots for large preventive maintenances every Tuesday for the upcoming week. Concurrently, the responsible planning unit on the freight railway side performs a database query for identifying locomotives with due large preventive maintenances within the next four weeks. With this two information, locomotives are determined, which will be maintained during the next week. The average number of locomotives, which have to be maintained every week, serves as planning orientation. If necessary, the planner brings forward some soon due maintenance tasks to balance the number of weekly large preventive maintenances. The responsible planning unit also tries to schedule preventive maintenances on days with typically low transport demand (e.g. Monday). The used time slots for large preventive maintenances are then communicated to repair shops and affected locomotives are blocked for operations during this time. The transfer of these locomotives to and from repair shops is planned one day in advance, when adjacent locomotive duties are definitely known.

The third group are *small preventive maintenances*. Depending on the type of locomotive and its annual performance, main line locomotives require several small preventive maintenances throughout the year. The duration of such small preventive maintenances is typically a few hours only. As shown in Figure 6-5, the process of planning small preventive maintenances in repair shops widely resembles the one for large preventive

maintenances. However, there is an important difference. Small preventive maintenances are purposefully planned in remaining idle times of locomotive tours. This influences the daily number of small preventive maintenances and determines their time slots.

**Figure 6-5: Process of preventive maintenance planning (locomotives)**



## 6.5.2 Discussion

The above-described process for planning large preventive maintenances of locomotives does not rely on information coming from shippers, such as forecasts or firm shipment orders. This is comprehensible, as the efficiency of repair shops depends on a balanced and coordinated workload. In this perspective, the number and date of future shipments is largely irrelevant. Furthermore, large preventive maintenances last up to two days. Even with exact information about future shipments, locomotive tours could often not be optimized by using idle times between two duties.

On the other hand, the process of planning small preventive maintenances of locomotives already fully considers firm orders of shippers. Small preventive maintenances are planned around locomotive duties, which are determined by shipment orders. The potential benefit of an intensified collaboration with shippers is regarded as little, if the above-described process remains unchanged. From the perspective of a freight railway, the process is nearly optimal for minimizing idle times of locomotives. It does not require

any further information from shippers. On the other side, repair shops have difficulties to plan their capacities and to ensure a balanced workload. They neither know the number nor the arrival time of locomotives with due small preventive maintenances until the day before.

An improvement could therefore be achieved for repair shops if the planning process of small preventive maintenances would start a couple of days earlier. No further information from shippers are needed for this process adaption, as the large majority of firm orders will be placed at this time already. Repair shops would gain more time for adjusting their staff size according to the effective workload by mandating overtime work or compensation days.

### **6.5.3 Collaborative Approaches**

To a limited extend, **using shipment forecasts for adjusting the availability of locomotives to actual demand** could improve planning of large preventive maintenances. Being aware of days with exceptional high transport demand, planners could reduce the number of large preventive maintenances more targetedly to ensure sufficient locomotives for operation. This enables a demand-oriented availability of locomotives. A large majority of shipments must be forecasted for identifying such peak demands. Prediction errors are acceptable to a certain extent, as they are used for identifying (exceptional) peaks and not for detailed planning. With regards to the planning horizon at repair shops, forecasts would have to cover a time horizon of at least two weeks. This measure requires certain flexibility at repair shops, as their repair capacities must be adaptable. Consequently, repair shops must hold overcapacities available, leading to increased maintenance costs.

Aggregated shipper forecasts could also be useful for small preventive maintenance planning if this process starts focusing on a more balanced and coordinated workload at repair shops rather than optimally utilized locomotive tours. Being aware of days with exceptional high transport demand, planners of small preventive maintenances could reduce the number of preventive maintenances at these times to ensure enough locomotives for operation.

## **6.6 Planning of Vacation, Overtime, and Toil**

### **6.6.1 Process**

Duty rosters for train drivers are basically elaborated in December for the entire upcoming year, based on the annual timetable and prior vacation planning. The general approach of this annual duty roster is depicted in Appendix C.

A few days before the date of transport, the annual roster of train drivers is updated according to revised duty schedules and actual traffic. Within this short period of time, the planning of overtime and time off in lieu (toil) are essential measures for planners. The

revision of duty schedules is completed – with exceptions – latest two workdays prior to the date of transport (Figure 6-2). Revised duty schedules affect the initial roster of train drivers if daily tours are extended, shortened, cancelled, or newly created. If a daily tour is extended, the roster planner must confirm the disposability of the foreseen train driver to work overtime or has to look for substitution otherwise. In case of shortened and cancelled tours, it is generally sufficient to inform affected train drivers<sup>42</sup>. If new tours have been created, roster planners must first identify suitable train drivers. Legal aspects (e.g. statutory rest time) as well as operational aspects (e.g. time balance of train drivers) must be considered for this decision. Suitable train drivers are then called successively until someone is available and willing to waive his free day. Although roster planners have decisional authority to oblige train drivers to work additional tours, such extra efforts are largely based on voluntariness in practice. A good understanding between roster planners and the crew of train drivers is essential for a high willingness and flexibility of train drivers to work extra hours or to take time off in lieu at very short notice.

Overall, the planning of overtime and time off in lieu enables a high flexibility to adjust the number of deployable train drivers according to actual need. This is regarded as an important advantage towards the deployment planning of locomotives and freight wagons, whose transport capacity is more difficult to adjust at short notice.

## 6.6.2 Discussion

Extra shipment orders and cancellations of shippers few days prior to the date of departure have a significant influence on the process of planning overtime and time off in lieu. There is very little time to change roster plans of train drivers and arrange overtime work or time off in lieu if initial schedules change few days prior to departure. This pronounced short-term nature is a main challenge of planning of overtime and time off in lieu. It is further complicated by numerous constraints coming from collective labour agreements. However, it is important to emphasize that arranging overtime and time off in lieu is usually possible within days and an important lever for adjusting the available number of train drivers.

Despite this flexibility, the reduction of short-term extra orders and subsequent modifications of already placed shipment orders would make planning much easier. The capabilities on shipper side will be limited, however. This implies the consideration that short-term modifications of initial transport plans are not in the interest of shippers either, as they generate cancellation fees and disturb schedules of shipper's vehicles. In general case short-term extra orders and subsequent modifications will therefore not be the result of careless planning but of unforeseen external incidents. In addition, the necessity of working overtime or taking time off in lieu is not always the consequence of changed train orders of shippers. Disturbances during the date of carriage such as blocked lines,

---

<sup>42</sup> Special conditions for the compensation of time apply if tours are cancelled after 17h on the day before duty.

delays, or sick train drivers may also make adaptations of duty rosters necessary. Due to its possible effect on statutory rest times, such operational changes in train driver rosters can lead to numerous adaptations in roster plans of the following days.

### **6.6.3 Collaborative Approaches**

The chance of finding train drivers for working overtime might increase if additional tours are known earlier than today. In this regard, the availability of reliable shipment forecasts can be of interest. Much more important for improving the productivity of planning overtime and time off in lieu is though the reduction of short-term extra orders and subsequent modifications of already placed shipment orders. In this regard, collaborative approaches are little suited, as the reasons behind are generally unforeseen external incidence, which are not under control of shippers. No collaborative approach was therefore identified for the process of planning overtime or time off in lieu, despite of its relevance for productivity at freight railways.

## **6.7 Distribution Planning of Empty Wagons**

### **6.7.1 Process**

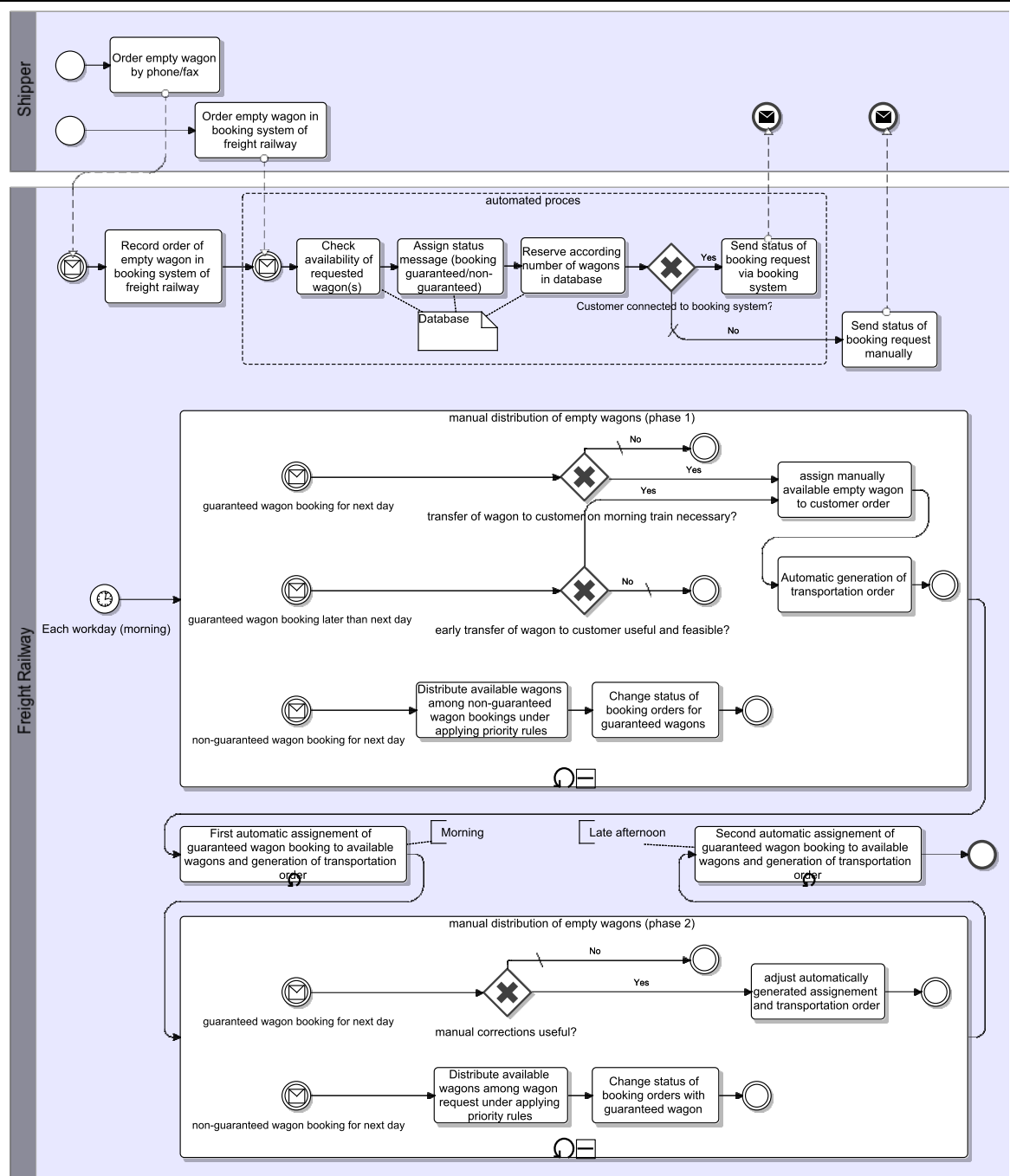
The booking of empty wagons is closely linked to distribution planning of empty wagons and therefore depicted first (Figure 6-6). Customers must send their empty wagons orders latest one workday (8h) prior to the requested day of delivery. This is possible via an electronic interface (standard procedure) or via phone, fax and email. The booking system automatically checks the availability and sets the status to “guaranteed” in case of sufficient available wagons. At the same time, the requested numbers of wagons are reserved in the database. As the duration of the wagon utilisation is unknown, the booking system makes an estimation on the basis of past data<sup>43</sup>. The booking is confirmed to the customer via the electronic interface or manually by phone, fax and email. If there are not enough wagons available at the time of booking, the booking request receives the status “non-guaranteed” and is communicated to the customer accordingly. This status remains unchanged until one day prior to delivery, when planners of empty wagon distribution manually check their availability again.

---

<sup>43</sup> Daily demurrage charges apply for delivered wagons, which are not released by shippers within the granted time for unloading (usually one day). This financial penalty creates a high incentive for shippers to unload and release delivered wagons as soon as possible.



Figure 6-6: Distribution planning of empty wagons



Distribution planning of empty wagon starts one day prior to delivery. The process starts early in the morning with a first phase of manually distributing empty wagons. For guaranteed bookings being due next day, it is checked whether the delivery to the customer requires a train departing the current morning already. In this case, an available empty wagon is assigned manually to such booking requests. The associated transportation order is then generated automatically. For guaranteed bookings being due within the next two or three days, it is checked whether an early (part-)delivery of requested wagons is useful and feasible. This especially applies if large amounts of empty wagons are booked for a single day and destination. The planner does not know the actual

utilisation level of trains. He therefore tries to reduce the risk of an overflow at scheduled trains by distributing the amount over several days. However, the availability of empty wagons and sufficient parking space at destination often sets tight limits for such measures. The third type concerns non-guaranteed bookings. The planner checks whether sufficient wagons have been released in the meantime to satisfy all non-guaranteed booking requests. If so, he can change their status to “guaranteed”. Otherwise, the planner is forced to make a prioritization based on pre-defined criteria.

This first phase of manually distributing empty wagons is followed by the principal distribution of empty wagons. A program automatically assigns each guaranteed booking to a freight wagon in a distance-optimal way and generates associated transportation orders. Some manual corrections might be necessary afterwards, e.g. if a planner knows from experience that certain freight wagons will be released during the day. Released empty wagons during the day are also used for changing the status of further yet non-guaranteed booking requests. A second (minor) automatic distribution of empty wagons finishes the process in the late afternoon.

There are two principal reasons why the process of distributing empty wagons is not fully automatized. If the automatic distribution of empty wagons is done from the beginning, all scheduled trains come into question for delivery. However, this would necessitate an earlier deadline for placing empty wagon orders, which is contrary to the needs of certain shippers. On the other hand, a single automatic distribution at the end of the day would significantly reduce the number of possible trains and thus causing distinct peaks of empty wagon flows. The described semi-automated process is an efficient compromise, which considers the interests of shippers as well as the need of a balanced share of empty wagons on trains.

## 6.7.2 Discussion

Only little information is demanded from shippers to book empty wagons today. Neither the leasing duration nor transport destination has to be indicated.

The booking system calculates the expected average utilisation period of ordered wagons on the basis of past data. This calculation is used to determine whether sufficient empty wagons will be available for a certain date to guarantee empty wagon requests. Hence, an imprecise calculation could lead to guaranteed but unsatisfiable bookings due to an insufficient number of available freight wagons. If one wants to minimize this risk, a safety factor must be added on the calculated average leasing durations. This increases the number of needed freight wagons and lowers their average booking rate.

The lack of information about the releasing time of booked wagons entails that an empty wagon can only be assigned to a new booking request, when it has actually been released by the previous shipper. Some freight wagons can therefore not be considered during the first automatic distribution of empty wagons, because they have not been released yet.

At last, an earlier booking of empty wagons would not improve the current process of distributing empty wagons. This is mainly because distribution planning of empty wagons relies on an “unlimited” capacity of trains today (chapter 6.3). A potential overflow of certain trains is therefore not a planning issue in this process. Such overflows are currently only detected on the date of transport and cause problems for other processes such as short-term timetable planning and roster planning of train-drivers, when extra trains must be organised at very short time.

### **6.7.3 Collaborative Approaches**

#### **6.7.3.1 Forecast of Releasing Date for Booked Freight Wagons**

The current approach for determining the number of available freight wagons for a specific date is based on data from past turnaround times. Particularly for small wagon type fleets with a large standard deviation of turnaround times, forecasts on leasing durations for booked freight wagons could lead to more accurate results. A higher accuracy would allow reducing the reserve capacity of such wagon types, leading to a higher average booking rate of remaining wagons.

Prediction errors are acceptable to a certain extent, as there is a chance of mutual compensation. Highly inaccurate forecasts however would lead to wrong guarantees for wagon requests and therefore lower service quality. Forecasts on leasing durations must at least cover a large majority of bookings for one critical wagon types. Uncritical wagon types could be managed as today. For this measure, it is sufficient to provide the forecasted leasing duration together with the empty wagon booking.

Forecasting the leasing duration for each wagon is associated with an additional effort on shipper’s side. Together with potentially needed penalties for wrong predictions, this collaborative approach could cause opposition on shippers’ side. The booking system and the underlying capacity calculation tool would have to be modified for being able to process the incoming forecast data. This will generate non-recurring IT-costs.

An implementation of this measure would also have to consider the current policy of wagon demurrage. Demurrages have a highly positive impact on the productivity of freight wagons, as there is a high incentive for shippers to release delivered wagons as soon as possible after unloading. However, it gives no incentive for shippers to provide forecasts about the expected overall leasing duration. A successful implementation would therefore make a modification necessary, such as a discount on wagon demurrage if forecasts about leasing durations are provided.

#### **6.7.3.2 Forecast of Releasing Time of Booked Freight Wagons**

The information from shippers, at what exact time their booked freight wagons are released for new transports, would make distribution planning of empty wagons itself more efficient. It enables the disposition of wagons, while they are still in use. This

increases the number of available wagons during the first automatic distribution of empty wagons, enabling a better result with reduced distances for empty wagon deliveries.

A high accuracy and level of detail are mandatory requirements for this approach. Otherwise, there is risk of guaranteed but possibly unsatisfiable empty wagon bookings. Advantageously, there is no threshold of a minimal share of wagons, whose releasing time is being forecasted. The more shippers provide this information, the higher the benefit. Freight wagons with missing releasing times could be managed as today.

Overall, the benefit of this measure for improving the efficiency of freight wagons is regarded as very limited. First, the knowledge about the expected time of released wagons is only valuable for wagons being released after the first automatic assignment of empty wagons. This is a minority. Second, planners already adjust and optimize existing wagon distributions with subsequently released freight wagons today, as long as they have not departed yet. The remaining potential for optimisation is accordingly reduced.

On the other hand, there is a risk of a non-cooperativeness on shipper's side. Shippers would have to provide very detailed and accurate information about the releasing time of empty wagons. As false information has an immediate effect on the service level (guaranteed but unsatisfiable empty wagon orders), forecast errors would therefore have to be punished financially. In addition, the algorithms for the automatic wagon distribution assignment logic would have to be adapted first, generating (non-recurring) costs.

Due to this disproportion of risks/costs and resulting benefit, the measure of forecasting releasing times of booked wagons is not recommended to be pursued.

### **6.7.3.3 Early Delivery of Empty Wagon Bookings**

Early information about future orders of empty wagons in combination with the information about future shipment orders would enable the freight railway to determine the expected utilisation level of trains in single wagonload service<sup>44</sup>. Distribution planning of empty wagons could use this information to level peak demands by delivering certain empty wagons earlier than requested on low-utilized trains. Empty wagon deliveries thus have the function of balancing objects to reduce the absolute number of scheduled trains in single wagonload network and to maximize the utilisation level of the remaining ones.

However, this measure will be implementable in exceptional cases only. It extends wagon turnaround times, which significantly qualifies the benefit of levelled traffic flows. If – as an example – distribution planning of empty wagons levels peak demands by delivering 25% of all empty wagons bookings one day earlier than needed, the average turnaround

---

<sup>44</sup> The minimal requirements of needed information as well as the potential risks and costs are identical with those of capacity planning in single wagonload (chapter 6.3.3.1).

time would already increase by 5%, assuming an average turnaround time of five days<sup>45</sup>. With a fleet of 10'000 freight wagons, 500 additional freight wagons would be necessary because of this measure. Presuming average procurement costs of 100'000 CHF per freight wagon and a depreciation period of 25 year, annual costs of 2 Mio CHF would be the result. This amount does not yet include the costs for additional maintenances and parking areas for empty freight wagons on shippers' sidings or at team stations of the freight railway. A large number of trains would have to be avoidable due to this measure to overcompensate these additional costs. The overall productivity gain of this measure is therefore – if at all – very limited.

In view of the high risks and implementation costs going along with this measure, the productivity gain of an early delivery of empty wagon bookings appears disproportionately low and is therefore not recommended to be pursuit.

## 6.8 Summary

Table 6-2 summarises the identified collaborative approaches for improving productivity at the freight railway. The individual aspects are structured in the four categories

- required information about future shipments,
- value of shipper information in function of covered transport volumes at the freight railway,
- expected productivity gain, and
- risks & costs.

### Required information about future shipments

In the course of the empirical analyses of freight rail processes, it became evident that potential collaborative approaches have very specific requirements on needed shipper forecasts. In this regard, four important characteristics have been identified as highly relevant. They are depicted in Table 6-1, together with their possible values.

The *accuracy* of shipment forecasts is the first essential feature. This study defines accuracy as ratio of the number of correctly predicted shipments to the total number of predicted shipments. It is difficult to indicate a minimally needed level of accuracy. In talks with production planning experts from the analysed freight railway, forecasts having an accuracy of less than 80% generally lose their value for planning purposes. Accuracies of less than 80% are therefore defined as “low”. In contrast, accuracies of

---

<sup>45</sup> The turnaround of freight wagons in single wagonload traffic generally lasts at least three days. On the first day, the empty wagon is delivered to the customer. On the second day, the empty wagon arrives at the customer, is loaded, and shipped on the same day to its destination. The wagon arrives its destination on the third day, is unloaded, and finally released for other transports. Many factors like delayed unloading or international shipments may increase though this minimal turnaround time. In turn, immediate reloading of freight wagons decrease turnaround times, for instance.

90% and more are defined as “high” in this study. It reflects the fact that such information is regarded as highly valuable for planners.

**Table 6-1: Characteristics of required information: Features and possible values**

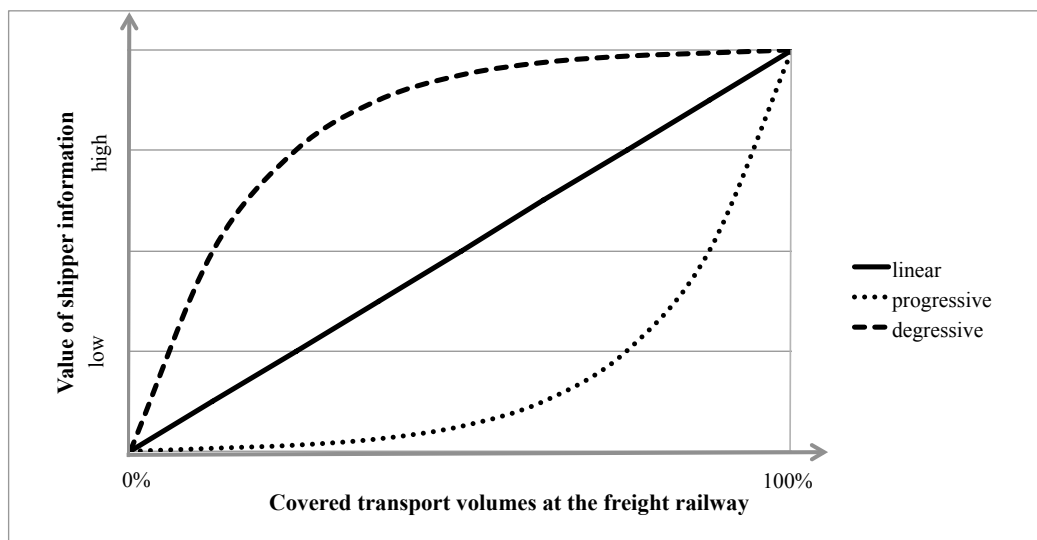
Feature		Value			
Shipper information	Accuracy	low	medium	high	
	Frequency	event-driven	monthly	weekly	daily
	Time horizon	≤ 1 week	2 - 3 weeks		≥ 1 month
	Level of detail	week	day	hour	

The second feature is the *frequency* of submitted forecasts to the freight railway. Depending on the actual use of provided information at freight railway, the minimally required frequency can vary from an event-driven up to a daily basis. In addition, the required *time horizon* and *level of detail* may differ as well. These are consequently two further considerable features.

### Value of shipper information in function of covered transport volumes at the freight railway

The value of provided forecasts from shippers depends on the covered transport volumes at the freight railway. In this context, there are three basic functions describing this correlation (Figure 6-7).

**Figure 6-7: Value of shipper information in function of covered transport volumes at the freight railway**



In the case of a *progressive* correlation, the value of provided shipper information is only given if it covers a high percentage of transport volumes at the freight railway. This requires the participation of a large majority of shippers. An example is the identification of traffic peaks, which is only possible when having a comprehensive picture about overall transport volumes. In the case of a *linear* correlation, the value of shipper information is proportionally increasing with the percentage of transport volumes

covered. The best possible case for a freight railway is a *degressive* function. This means that shipper information is highly valuable even if it covers a minority of overall transport volumes at the freight railway only.

### **Expected productivity gain and risks/costs**

The benefit, risks and costs of each identified productivity measure have been discussed in the respective chapters 6.2 - 6.7. The summary in Table 6-2 depicts these results in a concentrated form with four basic symbols:

- ↑ very positive effect on productivity; highly increased risks/costs
- ↗ positive effect on productivity; increased risks/costs
- no effect
- ↘ negative effect on productivity; reduced risks/costs

The expected productivity gain of the identified collaborative approaches is based on the elaborated requirements for high productivity in chapter 5.2. The risks are summarised to three major categories: The risk of reduced transport reliability<sup>46</sup>, the risk of opposition from shipper's side, and the risk of traffic losses. Generated costs in overhead – predominantly incurring in IT or planning – are qualitatively considered only. Note that the evaluation of productivity gains implicitly includes possible additional costs for assets and train drivers as well. Additional costs are generated if a measure has a negative effect on a requirement for high productivity.

---

<sup>46</sup> Reliability in freight transportation notably concerns the punctuality of shipped goods but also ensuring the shipment of negotiated transport volumes with customers.

**Table 6-2: Summary of identified collaborative approaches**

	Short-term timetable planning (block trains)				Short-term timetable planning (single-wagonload)		Leasing of rolling stock and personnel	Preventive maintenance planning	Distribution planning of empty wagons (single-wagonload)			
	Using shipment forecasts for joint levelling traffic peaks (Ch. 6.2.3.1)	Using shipment forecasts for optimising timetables and duty schedules (Ch. 6.2.3.2)	Placing shipment orders with flexible due dates (Ch. 6.2.3.3)	Taking charge of shipper's freight wagon scheduling (Ch. 6.2.3.4)	Publishing unused shipment time slots for block trains (Ch. 6.2.3.5)	Capacity planning of single-wagonload trains (Ch. 6.3.3.1)	Joint planning of feeder relations with dominant shippers (Ch. 6.3.3.2)	Using shipment forecasts for additional rolling stock and train drivers at traffic peaks (Ch. 6.4.3)	Using shipment forecasts for adjusting availability of locomotives to actual demand (Ch. 6.5.3)	Forecast of releasing date of booked freight wagons (Ch. 6.7.3.1)	Forecast of releasing time of booked freight wagons (Ch. 6.7.3.2)	Early delivery of empty wagon bookings (Ch. 6.7.3.3)
<b>Required information about future shipments</b>												
Accuracy	medium	high	high	high	-	high	medium	medium	high	high	high	high
Frequency	weekly	weekly	weekly	daily	-	event-driven	weekly	weekly	event-driven	event-driven	event-driven	event-driven
Time horizon	2 - 3 weeks	2 - 3 weeks	≤ 1 week	2 - 3 weeks	-	≤ 1 week	2 - 3 weeks	2 - 3 weeks	≤ 1 week	≤ 1 week	≤ 1 week	≤ 1 week
Level of detail	day	day and time	week	day and time	-	day	day	day	hour	hour	hour	day
<b>Value of shipper information</b> <sup>1</sup>	progressive	progressive	degressive	linear	-	progressive	progressive	progressive	linear	linear	linear	progressive
<b>Productivity gain</b>												
dense schedule of main line locomotives	↗	↗	↑	↗	- / ↗	-	-	-	-	-	-	-
few and short locomotive transfers	-	↗	↗	↗	-	-	-	-	-	-	-	-
dense schedule of engine drivers	↗	↗	↑	↗	- / ↗	-	-	-	-	-	-	-
few and short train driver transfers	-	↗	↗	↗	-	-	-	-	-	-	-	-
high rate of booked freight wagons	-	-	-	-	-	-	↗	-	-	-	-	↗
demand-oriented availability of locomotives	-	-	-	-	-	-	↗	↗	-	-	-	-
demand-oriented availability of employees	-	-	-	-	-	-	↗	-	-	-	-	-
low mileage of empty wagon transports	-	-	-	-	-	-	-	-	-	-	↗	-
maximized train utilization (length/weight)	-	-	-	-	-	↑	-	-	-	-	-	↗
low maintenance costs (locomotives)	-	-	-	-	-	-	-	↗	-	-	-	-
low leasing costs	-	-	-	-	-	-	↗	-	-	-	-	-
<b>Risks &amp; Costs</b>												
reduced transport reliability	-	-	-	↗	-	-	↗	-	-	-	↗	-
traffic losses	-	-	-	-	-	↗	-	-	-	-	-	↗
opposition from shippers	↗	-	↑	↗	-	↗	-	-	↗	↗	↗	↑
investment costs (IT, planning)	-	-	-	-	-	↑	-	-	↗	↗	↗	↑
operating costs (IT, planning)	↗	-	-	↗	↗	↗	-	-	-	-	-	↗

<sup>1</sup> in function of covered transport volumes at freight railway



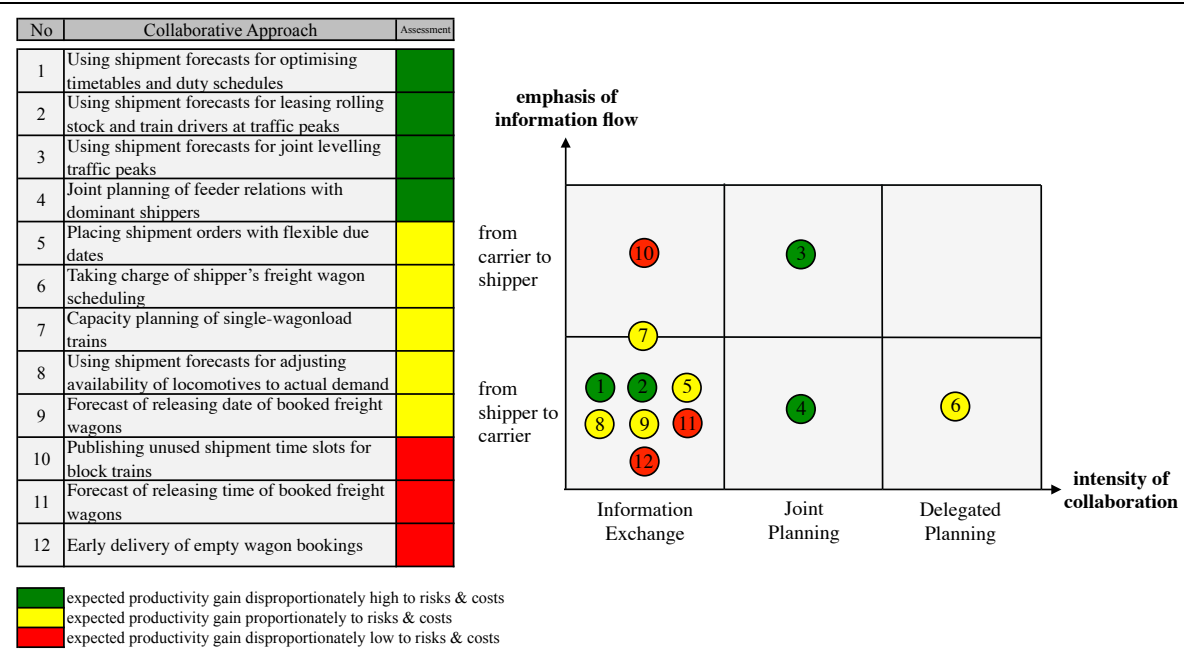
Several conclusions can be drawn from the results in Table 6-2:

- The characteristics of needed shipper information are considerably differing between identified collaborative approaches. This underlines the fundamental necessity of having a precise knowledge about what information shippers are able to provide and in which quality.
- Most collaborative approaches have been identified for the process of short-term timetable planning. This result justifies the generic evaluation in chapter 5.3. On the other end of the spectrum, no potential for collaborative approaches was found for the process of planning vacation, overtime, and toil.
- The identified collaborative approaches notably improve the efficiency of locomotives and train drivers. Approaches improving the effectiveness are less frequent and are focused on single wagonload traffic.
- Most identified collaborative approaches will expectedly generate little additional costs only.
- Large differences are noticeable for the expected level of shippers' opposition against identified collaborative approaches. One third of the twelve measures are regarded as uncritical, while one fourth will most likely face great opposition.

Inspired from WHIPPLE AND RUSSEL (2007), three intensities of collaborations are distinguished, ranging from information exchange – the least intensive form of collaboration – up to entirely delegating responsibility for certain planning tasks. In this regard, the complexity of implementation and the required mutual confidence generally correlates with the intensity of collaboration. In addition, collaborations usually show a primary flow of information. Figure 6-8 classifies the collaborative approaches according to these two characteristic features and synthesises the results of this chapter on a highly aggregated level. This synthesis allows formulating a number of interim conclusions about the identified collaborative approaches:

- Productivity gains for the collaborative approaches 1 to 4 are classified as disproportionally high, compared to the associated risks and costs. These measures should therefore clearly be pursued further. They suggest a comparatively easy implementation, thus justifying even a small total productivity gain.
- Productivity gains for the collaborative approaches 5 to 9 correlate with the expected risks and costs. Based on the available empirical data, it is not clearly estimable, whether these measures are worth to be implemented. More detailed and quantitative data are necessary for answering this question.
- The collaborative approaches 10 to 12 are not recommended to be pursued any further and this regardless of whether shippers are capable to provide needed information or not. Productivity gains are regarded as disproportionally low, compared to the associated risks and costs.

**Figure 6-8: Summary of results and classification of collaborative approaches**



The generic classification in Figure 6-8 clearly shows that most identified collaborative approaches concentrate on the exchange of information, notably from shipper to carrier. Collaborative approaches 3, 4 and 6 represent more intense forms of collaboration (joint planning and delegated planning), whereof the first two appear particularly promising. No collaborative approaches were found in the field of delegating planning tasks from carrier to shipper<sup>47</sup>.

The practical implementation of the identified collaborative approaches presupposes the ability of shippers to provide required information and the willingness to cooperate. The following chapters 7 and 8 will address these questions in detail. Further, the measures may require incentives for shippers and make organisational modifications necessary. Such implementation issues will be discussed in chapter 9.

<sup>47</sup> Delegating planning tasks such as the elaboration of timetables could be a suitable option for freight railways with one dedicated customer only (also known as industrial railway). As industrial railways only cover a marginal share of total rail freight performance in Switzerland, this option is not specifically considered in this study.

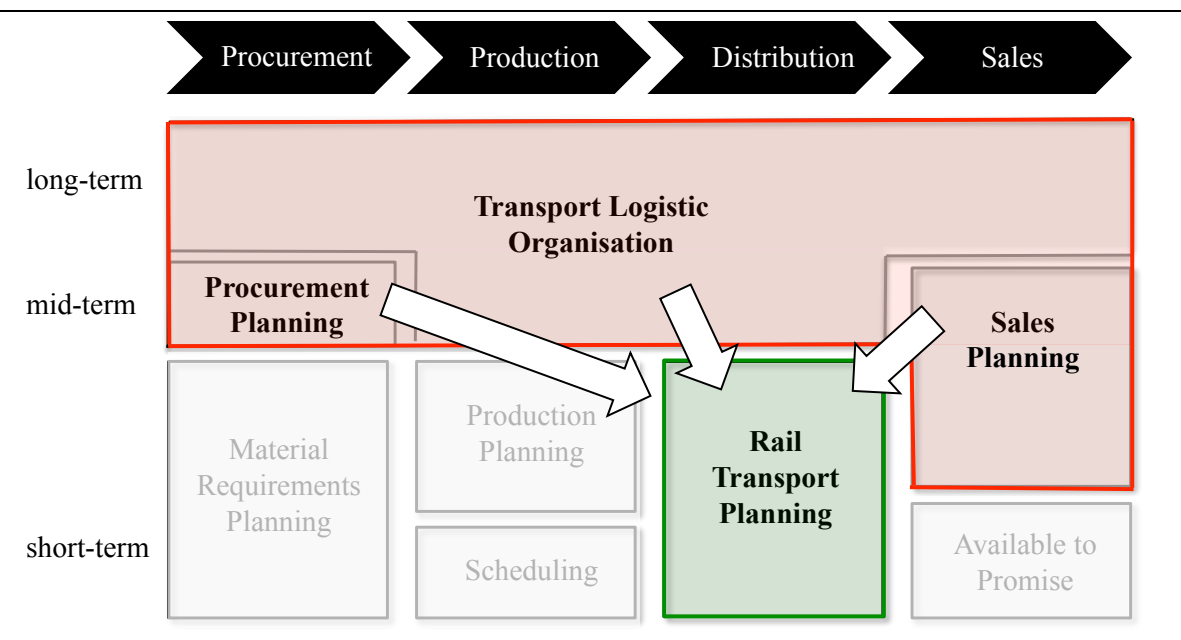
# 7 Framework for Analysing Shippers' Rail Transport Planning

## 7.1 Introduction

Many factors have an impact on shipper's rail transport planning. The following methodological framework provides a number of morphological schemes for describing impact factors in a structured and comparable way<sup>48</sup>. This helps understand the characteristics and quality of rail transport planning at shippers. Furthermore, the information can be used to determine the ability of shippers to prepare accurate forecasts and to compare it with actually submitted forecast and order qualities.

The basic structure of the elaborated morphological schemes was derived from the Supply Chain Planning Matrix of RHODE ET AL. (2000). An adapted version of this matrix is illustrated in Figure 7-1.

**Figure 7-1: Main areas with relevance to rail transport planning**



Source: Author / adapted from the Supply Chain Planning Matrix of ROHDE ET AL. (2000)

<sup>48</sup> For details about the applied method please refer to chapter 4.2.2.1.

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

- **transport logistics organisation** – defined as the infrastructure and organisational boundary conditions for transport planning; typical examples are inventory strategies at transport origins/destinations and the geographical distribution of goods being shipped;
- **sales/procurement planning** – essentially the pre-cursors to transport demand; vague estimates of sales/procurement volumes 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 from transport flexibility to the form and quality of forecasts and orders.

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 (e.g. [FLEISCHMANN ET AL. (2008)], [FRIES (2010)], [MEYER AND STADTLER (2008)], [SCHÖNSLEBEN (2004)]). While a series of in-depth personal interviews with transport experts at SBB Cargo and representative shippers were the main source of information.

The proposed morphological framework is organised in terms of category, sub-category, feature and values. In addition, the further right the values appear in the tables, the more advantageous are the conditions at shippers for providing accurate shipment forecasts to the freight railway. This approach is an effective visual aid to estimate shippers' overall predictive abilities as well as to identify features with particular positive/negative effects on transport planning at one glance.

## 7.2 Transport Logistic Organisation

### 7.2.1 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 7-1 presents the four transport planning features identified in this study for characterising a transport network.

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 proposed values of these two features have been derived from the empirical analyses of shippers in chapter 8.

**Table 7-1: Transport network structure: features and proposed values**

<i>Feature</i>	<i>Value</i>			
Number of origins	> 15	6 – 15	2 – 5	1
Number of destinations	> 15	6 – 15	2 – 5	1
Transport volume on top 20% of relations	< 50%	50% – 80%		> 80%
Network extent	international / long-distance		domestic / short-distance	

Planning complexity of networks is reduced if transports are mainly concentrated on few important relations. This can be measured by the distribution of transport volumes on the transport relations of a specific network. The proposed feature is *transport volume on top 20% of relations*, based on the number of shipped wagons. The higher this percentage value is, the more concentrated are transport volumes on few important transport relations of a transport network. Again, the proposed values of this feature have been derived from the empirical analyses of shippers in chapter 8.

Another relevant feature is the *network extent*. A network with long-distance and/or international (border crossing) transports is generally more challenging for transport planning, because the chance of delays increases. Moreover, 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 has a destabilising effect on transport planning.

## 7.2.2 Transport Responsibility

As shown in Table 7-2, transport responsibility consists of four main features impacting transport planning. The *number of involved railways per transport* 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.

**Table 7-2: Transport responsibility: features and proposed values**

<i>Feature</i>	<i>Value</i>		
Number of railways involved per transport	several		one
Provider of shipping-paid deliveries	yes		no
Enquirer of shipping-paid deliveries	no	yes, partly	yes
Entity responsible for releasing products being shipped	≠ freight payer		= freight payer

Shipping-paid deliveries are freight shipments where the supplier pays and organizes the transport to the company ordering the product being shipped. In an ideal world the

shipment would be forecasted by the company ordering the product, but in reality many companies are not doing so. Besides, partly using the service of shipping-paid deliveries can be highly advantageous for companies if they bear responsibility for transports of basic demands and use shipping-paid deliveries for peak demands. This strategy has a stabilizing effect on transport planning for *companies enquiring shipping-paid deliveries*, while the opposite effect occurs for *companies providing shipping-paid deliveries*. Their transport planning tends to become less stable and predictable.

Eventually if the *entity responsible for releasing products being shipped* is concurrently 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 the release of shipments.

### 7.2.3 Characteristics at Transport Origin and Destination

The third sub-category of transport logistic organisation focuses on the situation at transport origin and destination. As illustrated in Table 7-3 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.

**Table 7-3: Characteristics at transport origin and destination: features and proposed values**

<i>Feature</i>	<i>Value</i>		
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 at origin	exclusive		shared
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 at destination	exclusive		shared

The *quantitative flexibility of production capacity* describes the temporal flexibility of production capacity<sup>49</sup>. All other things being equal, a more flexible production capacity reduces the ability to forecast transportation demand precisely.

<sup>49</sup> This feature has been adopted from SCHÖNSLEBEN (2004).

*Inventory philosophy* describes an aggregated set of storage depot characteristics from the perspective of transport planning (since management of storage depots is a very complex optimisation problem, the measure proposed in this study ignores aspects of storage depot management that do not directly impact transport planning). This study 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 accuracy 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 invest 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 is expected to be well predictable if production is not flexible in terms of time and there is a minimum 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).

The *entity in charge of transport site* is another relevant feature. If the entity ordering transport 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. Otherwise, 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.

Shared *use of rail siding* eventually forces shippers 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 shippers that share sidings should be more accurate. A shared use of rail siding is found at joint-venture distribution depots, for example.

## 7.3 Sales/Procurement Planning

### 7.3.1 Shipper's Service Characteristics

The first sub-category of sales/procurement planning is the shipper's service characteristic. Table 7-4 presents its features and proposed values with relevance to transport planning.

The larger the *shipment lot size*, the more it affects rail transport planning. Block trains are the largest possible shipment lot size in freight rail. Modifying orders with such shipment lot sizes often necessitates a rescheduling of transport plans at both shippers and freight railway. Changes to shipment lot sizes in the range of single freight wagons typically have a small impact on scheduling due to the large number of possibilities for adding a freight wagon to another train.

If *delivery date flexibility* is not given, 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 modification: however these short-term modifications do not necessarily increase the potential for increased rail transport system optimisation. Quite the 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.

**Table 7-4: Shipper's service characteristics: features and proposed values**

<i>Feature</i>	<i>Value</i>		
Shipment lot size	block trains	freight wagons	
Delivery date flexibility	± 1 week or more	± 1 day	not flexible

### 7.3.2 Sales/Procurement Plan

Sales/procurement plans of shipping companies are the precursors to transport forecasts and 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 the result of numerous factors such as the volatility of sales demand, flexibility of sales terms, and intensity of collaboration between customer and shipper.

The time horizon and level of detail reflect the reasonably achievable accuracy in sales/procurement planning. As shown in Table 7-5, the longer the forecast period and the



more precise the level of detail (e.g. a daily forecast rather than a monthly forecast) the better.

There are two fundamental *forecast techniques*: intuitive forecasts and mathematical forecasts<sup>50</sup>. Sales/procurement forecasts based on mathematical forecasting techniques (which imply the existence of a quantifiable future demand behaviour) 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 then be necessary.

**Table 7-5: Sales/procurement plan: features and proposed values**

<i>Feature</i>	<i>Value</i>		
Time horizon	≤ 1 week	> 1 week	≥ 1 month
Level of detail	month	week	day
Forecast technique	intuitive	mathematical	none (firm orders)

It is important to note that accurate and long-term sales/procurement plans generally lead to accurate and long-term transport plans, 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 shipper must dispose of options to manage demand deviations without major changes to the initially elaborated transport plan (chapter 7.4.2).

## 7.4 Transport Planning

### 7.4.1 Transport Plan

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

The *time horizon* reflects the optimal time horizon for transport planning from the shipper's perspective. For the railway applies: the longer the time horizon is, the better.

The chosen *level of detail* can be either determined by planning uncertainty or needed accuracy. In general, shippers with monthly or weekly transport plans will not be able to specify transports in more detail. It is also conceivable, however, that there is simply no need for more detailed transport planning from the shipper's perspective. In either case, highly aggregated transport plans are of little value for freight railways.

<sup>50</sup> Predominant among mathematical forecasting techniques is the statistical extrapolation of a time series (e.g. linear regression or moving average forecast models). In turn, intuitive forecast techniques are mainly based on estimations from experts (e.g. Delphi Method). For details please refer to DICKERSBACH (2007) or SCHÖNSLEBEN (2004).

The *revision cycle* is another relevant feature. As shippers may order single wagonload services on a daily basis and block train services on a weekly basis (chapter 2.1.2), it is plausible to assume that revision cycles of transport plans are correlating to transport order frequencies. Principally possible are also event-driven revision cycles or even no revisions at all. In the best case there would be no revisions (indicating stable transport demand), while daily revisions would be the worst case (indicating highly unpredictable transport demand). In the middle are weekly and event-driven plan revisions. Event driven plan revisions can be almost as bad as daily plan revisions, depending on frequency and intensity of underlying events. Typical examples are unexpected sales or production breakdowns.

**Table 7-6: Transport plan: features and proposed values**

<i>Feature</i>	<i>Value</i>			
Time horizon	≤ 1 week	> 1 week		≥ 1 month
Level of detail	month	week		day
Revision cycle	daily	event-driven	weekly	no revision

## 7.4.2 Transport Flexibility

The transport flexibility sub-category consists of physical and operational characteristics of the shipper. If transport planning has no adequate options to cope with varying short-term demand, shipping volumes are compelled to be stable. However, this is generally not feasible in practice as it would be at the expense of other relevant factors such as increased stock capacities or inflexible conditions for delivery/supply. This is why transport planning should dispose of a set of measures to ensure certain flexibility. Four main features have been identified in this context (Table 7-7).

**Table 7-7: Transport Flexibility: features and proposed values**

<i>Feature</i>	<i>Value</i>		
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 ownership	ad-hoc leasing		proprietary possession / long-term leasing
Non-transport related measures for addressing demand deviations	none	few	many

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

The *latest possible time for placing transport order* reflects the fact that railways face strong competition from trucking, a mode that offers high transport flexibility, sometimes within hours. Therefore railways must also offer a comparable 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 feature *transport vehicle ownership* 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 utilisation, 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 of transport [SBB CARGO (2011)]. This enables shippers to rapidly adjust their shipping capacities according to actual demand. Without incentives for early wagon reservations, shippers have little incentive to develop stable long-term transport plans.

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

### **7.4.3 Provided Information to Railway**

The third sub-category of transport planning is the information provided by the shipper to the freight railway. This information can be forecasts or orders. In this study forecasts are defined as non-binding plans while orders involve a financial penalty for subsequent modifications. As shown in Table 7-8, there are seven relevant features concerning forecasts and shipping orders.

**Table 7-8: Provided Information to railways: features and proposed values**

<i>Feature</i>	<i>Value</i>			
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 accuracy	< 85%	85% - 90%	90% - 95%	> 95%
Dominant type of change (forecasts and orders)	cancel shipment	change date	change destination	additional goods to transport

The most important feature is *forecast accuracy*. In this study, forecast accuracy is defined as follows:

$$\text{forecast accuracy} = 1 - \frac{\text{number of changes at predicted shipments}}{\text{total number of predicted shipments}} \quad (7.1)$$

A change at predicted shipments can be a cancellation, a change of destination, or a change of shipment date. According to production planning experts at SBB Cargo, forecasts having an accuracy of less than 80% are generally either not transmitted to freight railways or otherwise not considered in production planning. The effort for subsequent modifications of initial planning would become too high.

The *share of shipments forecasted* 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 total shipped quantity of goods was actually forecasted. Low percentages can have two causes: Either forecasts are irregularly transmitted to freight railways (see below feature forecast frequency), or the shipper regularly underestimates the quantity of goods to be shipped. Notably in the first case, a systematic use of forecasts is highly difficult for freight railways.

Further 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.

Although subsequent modifications of transport orders are not in the interest of shippers, as they generate cancellation fees and disturb schedules of shipper's vehicles, unforeseen external incidents can make them necessary sometimes. This affects the *order accuracy* of shippers. In this study, order accuracy is defined as follows:

$$\text{order accuracy} = 1 - \frac{\text{subsequently changed and placed shipment orders}}{\text{total number of shipment orders}} \quad (7.2)$$

Note that the freight railway's acceptance of order changes and extra orders is a gesture of goodwill and an important negotiating point.

The *dominant type of changes (forecasts and orders)* reflects the fact that not all types of subsequent changes have the same implications on railways. 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 transport capacities.

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.

## **7.5 Summary**

The elaborated morphological schemes provide a structured framework for describing and analysing rail transport planning of shippers. The framework can help explain forecast and shipment order quality. It also helps detect and understand inconsistencies between expected and actually provided forecast and order information.

A further important benefit is the possibility to compare rail transport planning from different shippers and transport sectors using a uniform methodology. This enables railways to determine benchmark values for achievable forecast periods and accuracy levels of shippers. Freight railways can use these benchmarks to decide which shippers to pursue for accurate forecasts, and for which the effort is not warranted. This approach is notably useful if forecast data are not or only partly available from shippers.

The framework does not consider the experience and carefulness of people being responsible for transport planning and the efficiency of internal organisational procedures. Providing best practices and benchmarks to underperforming shippers could positively affect these soft factors.

# 8 Analysis of Shippers' Rail Transport Planning

---

## 8.1 Selection of transport sectors

This study aims to analyse three challenging transport sectors for transport planning. The approximate level of planning difficulty will be determined with figures indicating the deviation from the simplest possible planning situation. The simplest possible planning situation is given when

- weekly transport volumes,
- its percentage distribution over the week and
- transport relations

remain constant over time. A weekly period has to be chosen, as many rail transports repeat on this frequency. Preliminary data analyses have further shown, that measuring the variation of weekly transport volumes is well calculable and meaningful. However, the percentage distribution over the week is difficult to measure for some transport sectors. Especially in sectors demanding block train services, the number of daily trains may become critically low for valid statistical evaluations. The same applies for transport relations. The measurement of these two figures is therefore not always possible.

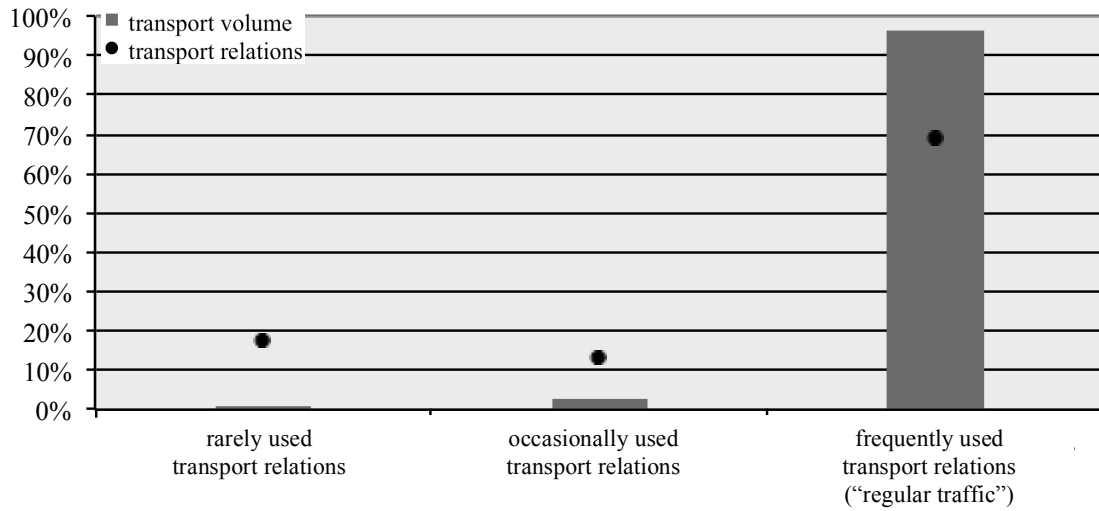
This is why a new indicator was created, called “regular traffic”<sup>51</sup>. This figure gives a concise indication for both the stability of transport relations and the percentage distribution of transport volumes over the week. Such regular traffic can generally be scheduled several months in advance with predefined weekdays of services. Hence, the higher the level of transport volumes is operated as regular traffic, the more stable becomes the percentage distribution over the week. At the same time, a high percentage of regular traffic does generally lead to a stable number of (frequently used) transport relations.

Figure 8-1 and Figure 8-2 illustrate the proposed approach for estimating the approximate level of planning difficulty on the example of intermodal transports. As expected, nearly the entire transport volume is operated as regular traffic (97%). In addition, the variation of transports volumes (based on block trains) is comparatively low with a standard deviation (STDV) of 8% only. These two quantitative figures indicate a low operational planning complexity.

---

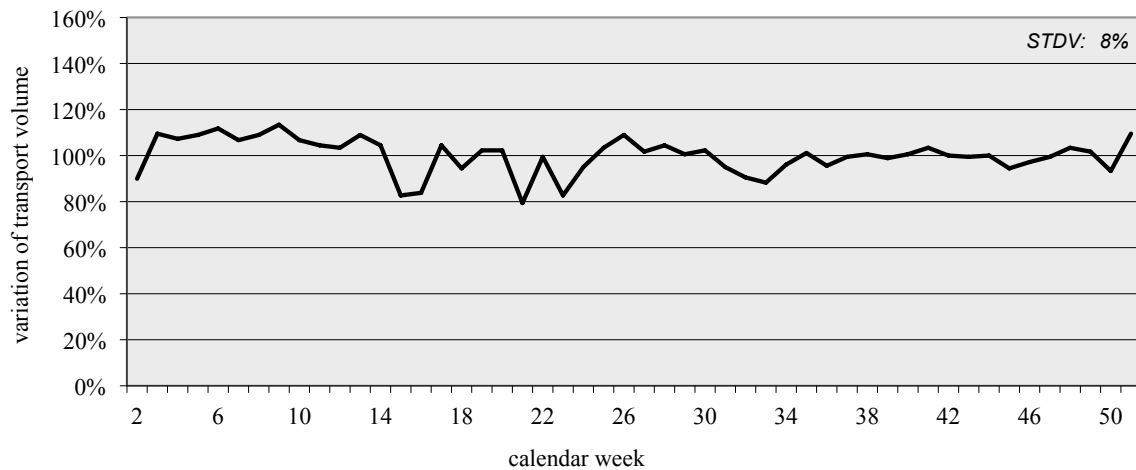
<sup>51</sup> For the definition please refer to Appendix D

**Figure 8-1: Share of regular traffic in intermodal transports**



Data: SBB Cargo (intermodal trains in Switzerland during 2009 without transit)

**Figure 8-2: Variation of weekly transport volumes intermodal transports**



Data: SBB Cargo (intermodal trains in Switzerland during 2009 without transit)

Analogue quantitative analyses have been conducted for the commodities/sectors mineral oil, gravel, tunnel excavation, and steel (Appendix D). The calculated indicators are depicted in Table 8-1 and disclose significant differences. They provide a valid base for estimating the approximate level of difficulty for the production planning at freight railways.

**Table 8-1: Calculated indicators for important transport sectors in Switzerland**

Commodity/Sector	Share of regular traffic		Standard deviation of weekly transport volumes
	based on transport volume	based on transport relations	
Intermodal transports <sup>1</sup>	97%	69%	8%
Tunnel excavation <sup>1</sup>	94%	59%	27%
Mineral oil <sup>1</sup>	65%	21%	11%
Gravel <sup>1</sup>	61%	29%	33%
Steel <sup>2</sup>	53%	15%	16%

<sup>1</sup> block train service <sup>2</sup> single wagonload service

Data: SBB Cargo (trains/wagons of respective commodities/sectors in CH during 2009 without transit)

*Intermodal transports* appear uncritical from the operational planning perspective. Nearly the entire volume of transport is operated as regular traffic. This is not surprising. Combined traffic operators assign freight railways to connect their intermodal terminals on the basis of fixed timetables [UIRR (2011)]. The number of possible transport relations is therefore limited and stable. Further, combined traffic operators offer at least weekly rail connections between terminals in order to stay competitive with pure road transports. This explains why intermodal rail transports largely meet the definition for being classified as regular traffic. The results also show a comparatively stable number of weekly trains with a standard deviation of 8% only. This is comprehensible as well. Forwarding agents and shippers need reliable timetables between terminals for organising their intermodal transport chain, including pre- and final carriage by road. In this regard, shippers would hardly accept short-term changes, as this could lead to severe delays in deliveries. Combined traffic operators therefore have to offer stable timetables for trains connecting terminals.

*Tunnel excavations* are also characterised by a high percentage of regular traffic (94%). The reasons are similar to intermodal transports. First, the number of possible transport relations is limited, as there are only few tunnel construction sites and suitable landfill destinations in Switzerland. Second, construction sites and landfills for excavations are known long time in advance and do not change during construction. However, the standard deviation of 27% for the weekly transport volumes is more than three times higher than for intermodal transports. At first view, this implies a challenging planning for the freight railway. The temporal development over time reveals though, that significant drops in transport volume largely correspond with typical times of low demand like Christmas, Easter time or the holiday month of August (Appendix D). Such periods will be operated according to a predefined holiday schedule, which is why most of these deviations are timely foreseen in planning. Despite of these deviations, trains with excavated materials from tunnel construction sites are thus rather uncritical for the operational planning of freight railways.



In contrary to intermodal transports and tunnel excavations, *mineral oil* appears to be a challenging commodity for freight rail planning. The share of regular traffic on total transport volumes is at 65% only. 79% of all transport relations are used occasionally or rarely, with comparatively little volumes of transport. This situation tends to make planning difficult. The overall number of weekly trains is rather stable in the mineral oil sector with a standard deviation of 11%. The temporal development shows no evident explanations.

A high planning complexity is expected for trains shipping *gravel*. Both key figures are strongly unfavourable. The share of regular traffic on total transport volumes is at 61%. This is comparable to mineral oil transports. However, the gravel transport sector additionally shows a high volatility with a standard deviation of 33%. Data show a distinct lower demand during winter, which well corresponds with the activity level on construction sites. Nevertheless, volatility remains high throughout the entire year. The combination of volatile transport volumes with a low share of regular traffic appears to be highly demanding for planning. Neither the overall weekly volume of transport, its percentage distribution over the week, nor transport relations can be regarded as stable.

Steel products and steel scrap are typically shipped as single wagonloads within Switzerland. The single wagonload network connects hundreds of service points in Switzerland on a regular basis. As many shippers and transport sectors use this network, timetables do generally not change at short-notice. The low share of regular traffic in the steel sector (53% of total transport volume) will therefore not have a direct influence on the operational planning at the freight railway<sup>52</sup>. The weekly transport volume (based on shipped wagons) varies with a standard deviation of 16%. Despite of largely fixed timetables, volatile transport volumes and an uneven percentage distribution over the week may nonetheless make planning in single wagonload network difficult. This is when freight railways specifically want to optimise utilisation levels of certain single wagonload trains. This optimisation is particularly challenging for trains, which are largely dominated by few shippers, whose transports are difficult to predict.

Based on these results, the commodities *mineral oil*, *gravel*, and *steel* appear particularly challenging for transport planning and are thus selected for further detailed empirical analyses (chapters 8.2 - 8.4).

---

<sup>52</sup> In fact, a low share of regular traffic is highly plausible for sectors shipping their products as single wagonloads. This service is predestined for flexible small-size shipments to diverse destinations. Otherwise, block trains would be the service of choice.

## 8.2 Mineral oil

### 8.2.1 Introduction

#### 8.2.1.1 Products

Refined petroleum products are derived from crude oils through fractional distillation [BOPP ET AL. (1996)]. They are separated according to the boiling point range of the compounds and their end use of application. Table 8-2 lists the typical fractions of crude oil, starting with the lowest boiling point at the top.

**Table 8-2: Typical crude oil fractions and uses**

Crude Fraction	Typical Uses
Hydrocarbon gas	Fuel gas
Gasoline	Motor fuel
Kerosene	Jet fuel
Light gas oil	Diesel fuel, heating oil
Heavy gas oil	Bunker fuel, lubricating oil
Lubricants and waxes	Lubricating oil, paraffin wax
Residuum	Tars, paving asphalts

Source: BOPP ET AL. (1996)

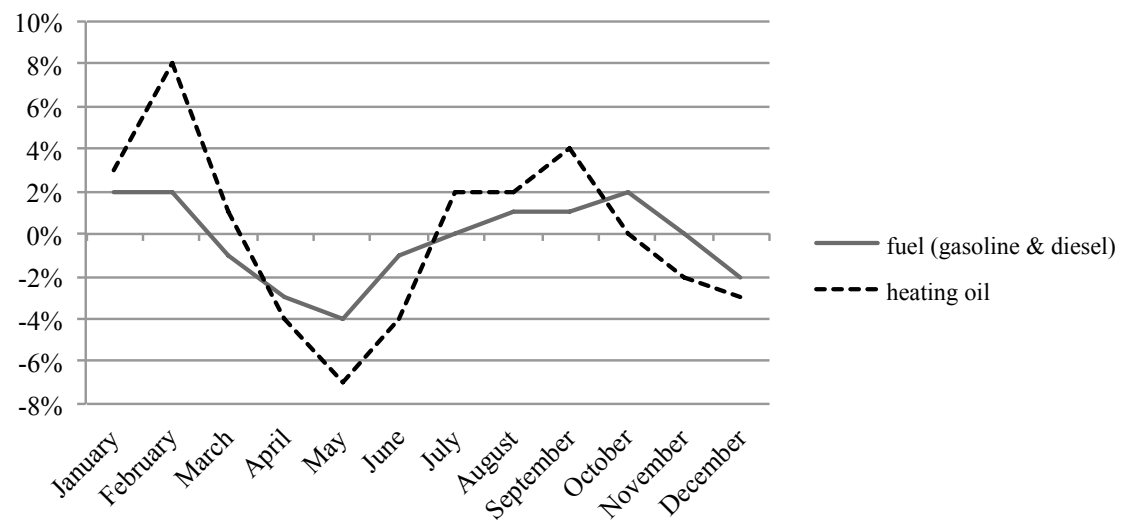
According to the Swiss Federal Statistical Office, around 950 millions tons-km of refined mineral products were transported on rail in 2010 (Table 2-1)<sup>53</sup>. This is around 9% of total rail freight performance in Switzerland.

Fuel<sup>54</sup> and heating oil are by far the most important refined products with a share of 58% respectively 37% of total demand [EV (2009)]. 39% of this demand is produced in the two domestic refineries in Collombey and Cressier, which are exclusively supplied by pipeline [EV (2010)]. The remaining 61% is imported from Germany, Netherlands, Italy, Belgium, and France. The most important transport modes for importing fuel and heating oil are block trains (41%), Rhine vessels (39%), trucks (11%), and pipelines (9%). The vast majority of block trains originate from Germany with a share of 70%.

The mineral oil market is generally characterised by a high price competition and significant price volatility (Figure 8-3).

<sup>53</sup> On the plausible assumption that no coke is shipped in Switzerland.

<sup>54</sup> Gasoline, jet fuel, and diesel fuel

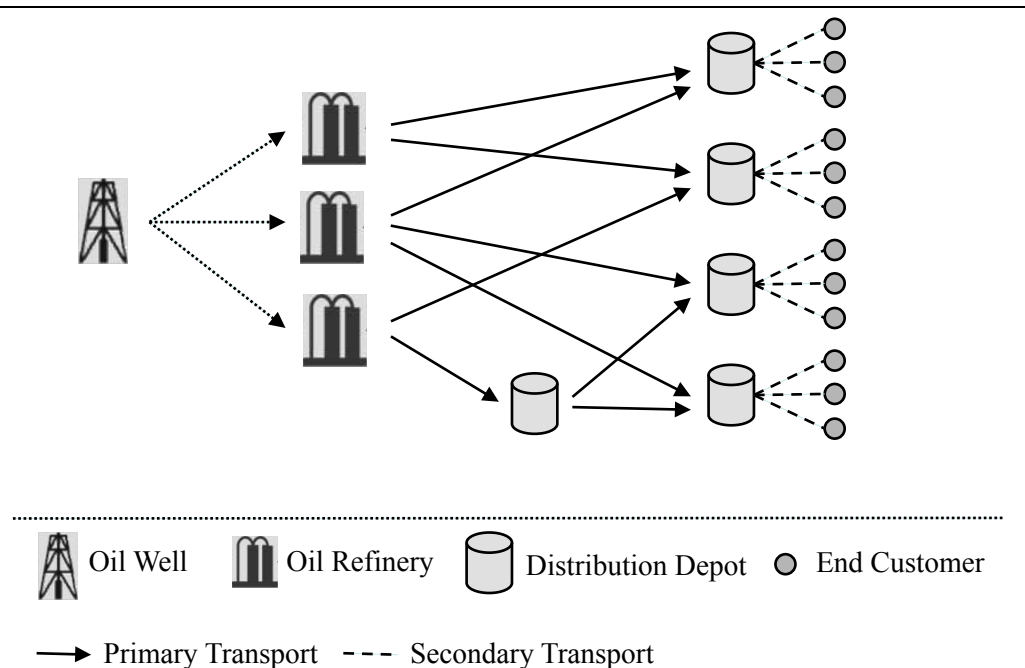
**Figure 8-3: Price volatility of fuel and heating oil in Switzerland**

Source: Swiss Federal Statistical Office; averaged values from 2010

In this regard, numerous influencing factors make reliable forecasts of prices for both heating oil and fuel nearly impossible [EV (2010)]. As customers of heating oil generally dispose of significant storage capacities, they can await the convenient time for buying heating oil. This behaviour can have a significant and immediate effect on physical short-term demand of heating oil.

### 8.2.1.2 Supply Chain Description

The crude oil is produced all over the world and transported via ship and/or pipeline to refineries (Figure 8-4). The refineries extract different quota of products like gasoline, diesel, or heating oil. Their refinery capacities are largely fixed and extensions demand long lead times and investment costs [ROITSCH AND MEYR (2008)]. The transport of finished products to end customers is divided into *primary transports* and *secondary transports* [SEAR (1993)]. Primary transports are conducted from refineries to distribution depots and between distribution depots. Distribution depots have one or several tanks for the bulk storage of mineral oil products. They may be owned by one company or operated as joint ventures. Typical transport modes are trains, ships, or pipelines. Within Switzerland, primary transports are largely rail-based. The final transport from distribution depots to end customers is entitled as *secondary transport* and usually done by truck.

**Figure 8-4: Supply chain structure in the mineral oil industry**

Source: Author / based on SEAR (1993) and ROITSCH AND MEYR (2008)

## 8.2.2 Empirical Results

### 8.2.2.1 Data Base

Six representative shippers (mineral oil companies) were selected from Switzerland to analyse rail transport planning and its key influencing factors in the mineral oil sector. The empirical research was conducted with guideline-based face-to-face interviews during 2010 with people being responsible for rail transport logistics at the selected shippers. During interviews, additional materials were sometimes provided, such as company documents, reports, and presentation materials. The interview guideline was structured in four sections, which have been arranged in a time-logical order: basis for planning, transport planning procedure, forecast/order transferring, and short-term change management (Appendix E). The shippers were selected according to their approximate shipping volume in Switzerland. The number of loaded trains per week varies at selected shippers between around 5 and 20. Within this range, selected shippers can be classified as large-size shippers (1 and 2), medium-size shippers (3 and 4), and small-size shippers (5 and 6). Refineries as well as trading companies are represented in this selection. Despite of the small sample of shippers, the results will be representative as they are responsible for the large majority of mineral oil transports in Switzerland

SBB Cargo provided additional data to analyse the accuracy of submitted train orders and forecasts. Provided data cover the period from calendar week 2 to 51 in 2009 and

comprise several thousands loaded trains of fuel<sup>55</sup> and heating oil in Switzerland (both domestic and import<sup>56</sup>).

Each shipper forecast, order, or subsequent modification of mineral oil trains has been complemented with their submission date to the freight railway. Cancellations, changed transport dates and changed destinations were counted as subsequent modifications. All shippers provided their forecasts on a voluntary basis to the freight railway. It is therefore assumed that submitted forecasts represent the maximal predictable period of time, which seems reasonable from the shippers' point of view. The plausibility of data analyses was subsequently checked with people being responsible for the operational planning of mineral oil trains on the freight railway side.

The results of the qualitative interviews and quantitative transport data are comparable, despite of their time shift of one year. No significant change with relevance to transport planning has occurred between 2009 and 2010 (e.g. new order conditions or transport strategies).

### 8.2.2.2 Transport Logistic Organisation

Table 8-3 shows that mineral oil rail transports in Switzerland origin from few destinations and supply numerous distribution depots throughout the country with heating oil and fuel. The percentage of transport volumes on top 20% of relations is consistently between 50%-80%. In contrary to the number of transport origins, the number of transport destinations is not always determinable exactly, as this figure depends on incoming orders from shippers' customers. Within the analysed period of time, shippers 1 to 3 serviced more than 15 destinations, while shipper 4 was close below 15. The number of serviced destinations is stable at small-size shippers 5 and 6 and varies between 2 and 15. The stable number of destinations is due to the fact that they do not supply their customers with entire block trains. All trains of shippers 5 and 6 supply their own distribution depots only.

All large- and mid-size shippers provide shipping-paid trainloads of heating oil and fuel to their customers. In contrast, the analysed small-size shippers partly take advantage of this service without offering it by themselves.

The network of rail transports is limited to Switzerland for most of the analysed shippers. Rail transport distances thus range between around 100 km and 300 km. An exception is shipper 4, which supplies its distribution depots in Switzerland internationally. Several freight railways are involved in this international transport chain.

<sup>55</sup> Gasoline, kerosene, and diesel fuel

<sup>56</sup> Imports with destination to Basel have been excluded. The rail-performance of these trains is negligible low on Swiss territory.

**Table 8-3: Transport network & responsibilities: results**

<i>Feature</i>	<i>Shipper 1</i>	<i>Shipper 2</i>	<i>Shipper 3</i>	<i>Shipper 4</i>	<i>Shipper 5</i>	<i>Shipper 6</i>
Number of origins	2 – 5	2 – 5	1	2 – 5	2 – 5	1
Number of destinations	> 15	> 15	> 15	6 – 15	6 – 15	2 – 5
Transport volume on top 20% of relations	50% – 80%	50% – 80%	50% – 80%	50% – 80%	50% – 80%	50% – 80%
Network extent	domestic / short-distance	domestic / short-distance	domestic / short-distance	international / long-distance	domestic / short-distance	domestic / short-distance
Number of railways involved per transport	one	one	one	several	one	one
Provider of shipping-paid deliveries	yes	yes	yes	yes	no	no
Enquirer of shipping-paid deliveries	no	no	no	no	yes, partly	yes, partly
Entity responsible for releasing products being shipped	= freight payer	= freight payer	= freight payer	= freight payer	= freight payer	= freight payer

Transport origins are either distribution depots or refineries (Table 8-4). The large majority of rail transports of shippers 1 and 2 depart from their refineries. The quantitative flexibility of these refineries is not flexible in terms of time. That means only minor modifications in production output are possible within at least a weekly time period. Further, depots storing the production output of the refineries have a minimum inventory capacity only. This is also why inventory accounting at refineries is done at production input level (crude oil). Hence, the production output of these refineries must be shipped away to larger distribution depots within days. A small part of rail transports from shippers 1 and 2 additionally origins from distribution depots (e.g. in Swiss Rhine Ports). All trains of shippers 3, 5, and 6 depart from distribution depots in Swiss Rhine ports. The inventory size of such distribution depots has been classified as medium. Company 4 is the only one of the six selected mineral oil companies, whose rail transports origins from refineries outside Switzerland. Their inventory philosophy is unknown.

Five out of six analysed shippers control their transport origin sites. In this case, operational transport planning and inventory management is done within the same organisational unit. At shippers 1 and 2, these organisational units are also in close contact with production planning of refineries and in-house train loading staff and scheduling. Shipper 4 does not control inventory at its transport origin sites.

The characteristic of transport destinations is similar at analysed shippers. All destinations consist of (mostly large) distribution depots with a medium inventory. In many cases, distribution depots are operated as joint ventures. This means that shippers (mineral oil companies) are jointly using available storage capacities. Nevertheless, each mineral oil company independently manages its own storage capacity. This constellation applies for all destination sites of companies 5 and 6 and for the majority of destination sites of companies 1 to 4. The latter also supply distribution depots of customers demanding shipping-paid delivery. In this case, they have no control over storage capacities and filling levels.

**Table 8-4: Transport origin and destination: results**

		<i>Shipper 1</i>	<i>Shipper 2</i>	<i>Shipper 3</i>	<i>Shipper 4</i>	<i>Shipper 5</i>	<i>Shipper 6</i>
<b>Transport Origin</b>	Quantitative flexibility of production capacity at origin	not flexible in terms of time	not flexible in terms of time	-	not flexible in terms of time	-	-
	Inventory philosophy at origin	minimum inventory <sup>1</sup>	minimum inventory <sup>1</sup>	medium inventory	n/a	medium inventory	medium inventory
	Entity in charge of origin site	= freight payer	= freight payer	= freight payer	≠ freight payer	= freight payer	= freight payer
	Use of rail siding	exclusive	exclusive	exclusive	shared	shared	shared
<b>Transport Destination</b>	Quantitative flexibility of production capacity at destination	-	-	-	-	-	-
	Inventory philosophy at destination	medium inventory	medium inventory	medium inventory	medium inventory	medium inventory	medium inventory
	Entity in charge of destination site	= freight payer <sup>2</sup>	= freight payer <sup>2</sup>	= freight payer <sup>2</sup>	= freight payer <sup>2</sup>	= freight payer	= freight payer
	Use of rail siding	shared <sup>2</sup>	shared <sup>2</sup>	shared <sup>2</sup>	shared <sup>2</sup>	shared	shared

<sup>1</sup> a minority of origins are distribution depots with medium inventory and shared use of rail siding  
<sup>2</sup> majority of destinations

The joint operation of distribution depots has an important effect on transport planning, as rail sidings are jointly used as well. This necessitates an early coordination to distribute the limitedly available loading/unloading time slots in a non-discriminating way. This applies for the majority of distribution depots at both transport origins and destinations.

### 8.2.2.3 Sales Planning

Shipment lot sizes are in the range of block trains (Table 8-5)<sup>57</sup>. The supplied distribution depots generally have enough inventory capacities to enable a flexibility of  $\pm 1$  day for supplying trains. Depending on actual demand and storage level, even a higher flexibility is sometimes possible.

**Table 8-5: Sales planning: results**

		<i>Shipper 1</i>	<i>Shipper 2</i>	<i>Shipper 3</i>	<i>Shipper 4</i>	<i>Shipper 5</i>	<i>Shipper 6</i>
Shipment lot size		block trains	block trains	block trains	block trains	block trains	block trains
Delivery date flexibility		$\pm 1$ day	$\pm 1$ day	$\pm 1$ day	$\pm 1$ day	$\pm 1$ day	$\pm 1$ day
<b>Fuel</b>	Time horizon	$\geq 1$ month	$\geq 1$ month	$\geq 1$ month	$\geq 1$ month	$\geq 1$ month	$\geq 1$ month
	Level of detail	month	month	month	month	month	month
	Forecast technique	mathematical	mathematical	mathematical	mathematical	mathematical	mathematical
<b>Heating Oil</b>	Time horizon	$\geq 1$ month	$\geq 1$ month	n/a	$\geq 1$ month	$\geq 1$ month	$\geq 1$ month
	Level of detail	month	month	n/a	month	month	month
	Forecast technique	intuitive	intuitive	intuitive	intuitive	intuitive	intuitive

All analysed shippers ship both fuel and heating oil by rail. Their demand characteristics largely differ from each other and must therefore be discussed separately. For reasons of confidentiality, the percentage of fuel and heating oil transports among the companies may not be indicated. The heating oil represents a significant part in rail transports of all companies, however.

<sup>57</sup> There are few exceptions from this general rule, which are not further considered in this study

Fuel demand is accurately predictable. Sales volumes of fuel are quite stable over the year, showing little seasonality and price-sensitivity. Hence, future demand is well calculable by means of mathematical forecasting techniques using past demand data. A monthly-based level of detail is generally sufficient, as fuel demand can equally be distributed over a month without risking a reduced forecast quality.

In contrary to fuel demand, heating oil demand is highly difficult to predict. All interviewed experts agreed on that. The main reason is a high price volatility of heating oil in combination with a distinct price-sensitivity of end customer demand. This hinders accurate sales forecasts as prices largely depend on the price of oil on world markets. In addition, there is often a time shift between sales and physical delivery of heating oil from distribution depots to end customers. Wholesalers are free to pick up their orders within a predetermined period of time. This can be up to several weeks. The time of physical output from distribution depots to end customers is therefore not exactly determinable, even when sales volumes were exactly known. Under such conditions, it is possible to observe a sharp increase of physical output within shortest time. This might be the case after a cold snap, coinciding with low filling levels of heating oil in households. Despite of these unfavourable circumstances, a rough estimation of sales demand is nevertheless necessary for purchasing and transport planning. Initial transport plans generally refer on sales plans, which predict the aggregated sales during one month. These sales estimations are usually made intuitively by interpreting available data such as existing heating oil orders, market price developments, or filling levels of heating oil at households. This requires a sound expert knowledge.

### **8.2.2.4 Transport Planning**

#### *8.2.2.4.1 Process*

Rail transport planning in the mineral oil sector is typically divided in a rolling monthly planning process and an event-driven short-term planning process. Figure 8-5 depicts the typified monthly transport planning process.

The process starts with an estimation of monthly customer demand by the sales and/or production department. The logistics department then equally distributes the received demand estimation over the month to calculate the approximate number of needed trains. Beside this in-house demand estimation, some medium- and large-size shippers additionally receive monthly train schedules from their customers, comprising the number of fuel or heating oil trains for each day and destination. Based on this information, the logistics department schedules their available tank wagon compositions for the entire planning month. The main target is to avoid idle times for own tank wagon compositions. This planning must consider and coordinate available time slots for loading/unloading trains at distribution depots, which are operated as joint ventures. This is done within an allocation process, starting around ten days before the end of each month. The reservation of time slots for loading/unloading trains is principally possible at any time. However, not



participating in this early allocation process would carry the risk of not getting suitable slots anymore. The result of the monthly planning is a provisional train schedule, comprising the number and approximate transport time of fuel and heating oil trains for each day and destination for the upcoming month.

**Figure 8-5: Typified monthly planning process**

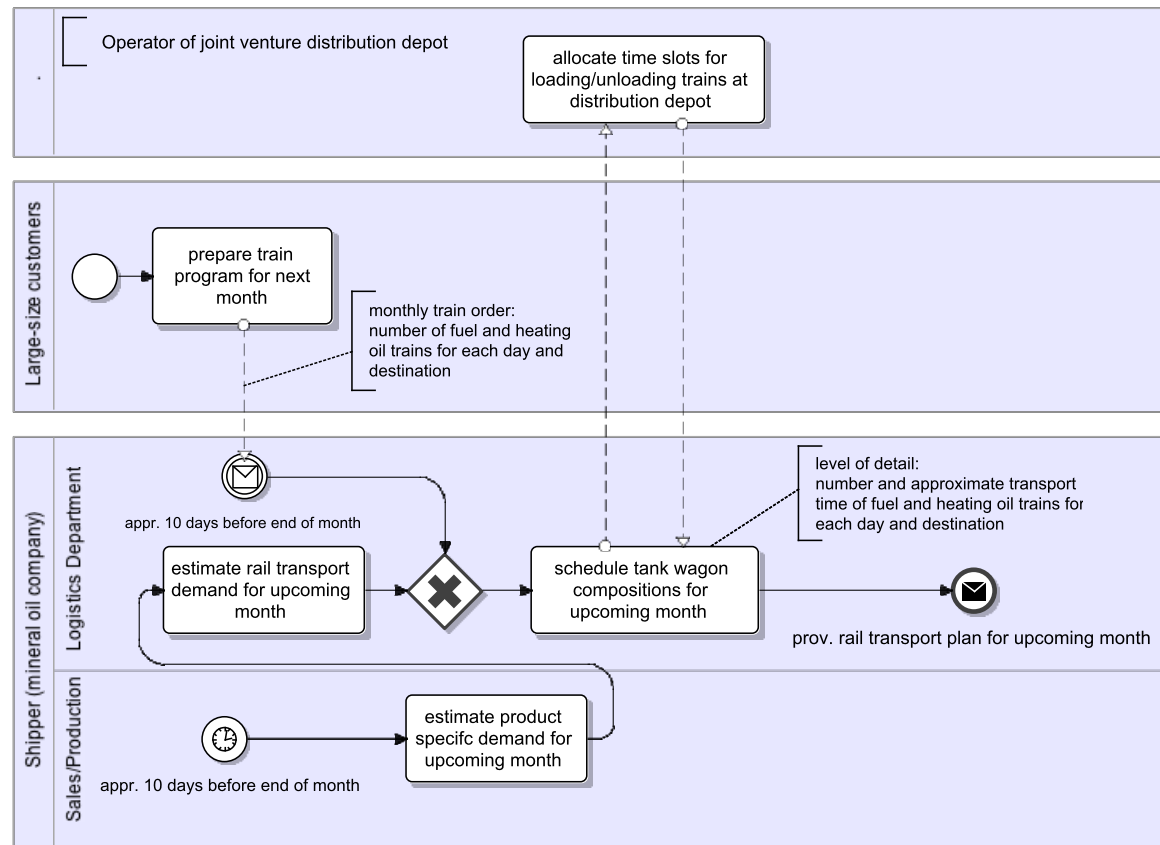
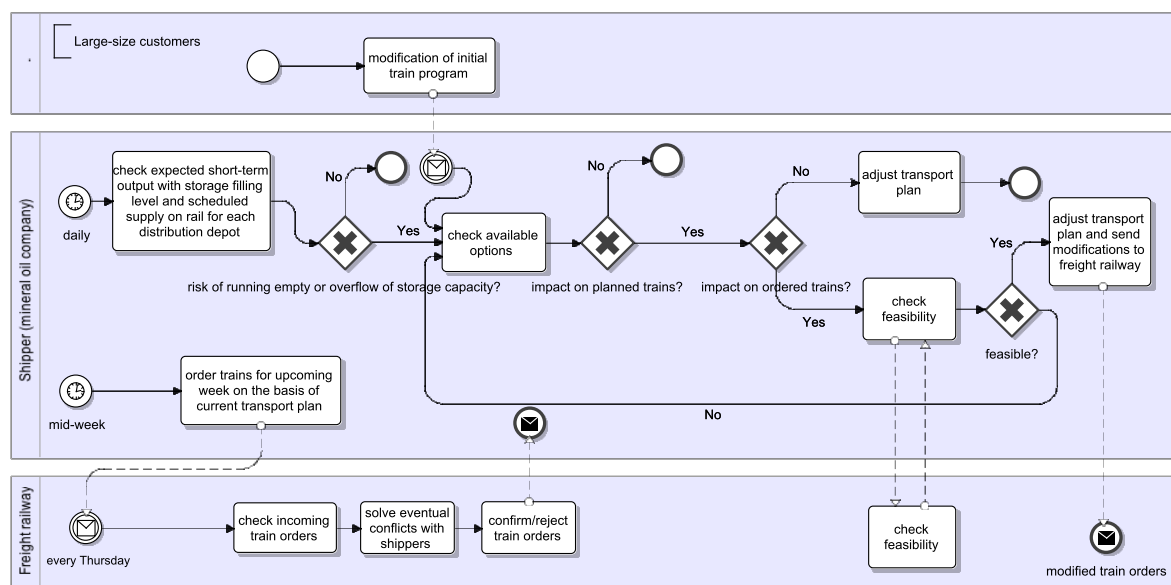


Figure 8-6 depicts the typified event-driven planning process during the month. An essential task is the continuous comparison of expected short-term output of distribution depots with depot filling levels and scheduled supplies on rail. If there is a risk of running empty or overflow of tank capacities, appropriate measures have to be taken timely (chapter 8.2.2.4.2).

Subsequent modifications of train programs from large-size customers, however, do often have a direct impact on planned or even ordered trains. In this regard mineral oil shippers basically apply the same train cancellation rules for their large customers as they have agreed on with their freight railway.

Eventually, mineral oil shippers submit their train orders to freight railways around mid-week for the upcoming week. Subsequent modifications occur even after this time of order. In this case though, additional train requests are not guaranteed and cancellations of trains may be subject of extra charges.

**Figure 8-6: Typified event-driven planning process during the month**

#### 8.2.2.4.2 Characteristics

Table 8-6 shows the basis characteristics of transport planning at analysed shippers.

As seen in the previous chapter, shippers of mineral oil products typically elaborate their initial transport plans at the end of each month for the upcoming month. They thus cover a time period of one month at most. These transport plans are already day-specific, although underlying sales plans often have a higher aggregation level with significant uncertainties. Only company 3 has indicated to start the major part of planning one week before departure, while block trains orders of large customers are also planned on a monthly basis.

Shippers 1 and 2 have regular weekly revision cycles during months for updating initial transport plans. All other companies follow an event-driven approach. In this case, it is checked on a daily basis, whether planned shipments have to be adjusted or not in the upcoming seven days. The latest possible time for placing train orders at the freight railway is Thursday prior to the week of departure. Subsequent modifications are possible but can be subject of extra charges.

Analysed shippers lease their rail tank wagons in long-term contracts<sup>58</sup>. Transport capacities therefore remain constant within at least several months and shippers have an immediate financial interest to fully utilise their leased rail tank wagons. This requires regular and equally distributed shipments, which is highly congruent with the interests of the freight railway.

<sup>58</sup> An exception is company 5, which has delegated the leasing and scheduling of rail tanks wagons to the freight railway. In turn, the shipping company commits to ship a certain yearly amount of fuel and heating oil.

**Table 8-6: Transport planning: results**

	<i>Feature</i>	<i>Shipper 1</i>	<i>Shipper 2</i>	<i>Shipper 3</i>	<i>Shipper 4</i>	<i>Shipper 5</i>	<i>Shipper 6</i>
Transport Plan	Time horizon	≥ 1 month	≥ 1 month	≥ 1 month <sup>1</sup> / ≥ 1 week	≥ 1 month	≥ 1 month	≥ 1 month
	Level of detail	day	day	day	day	day	day
	Revision cycle	weekly <sup>2</sup>	weekly <sup>2</sup>	event-driven (daily checking)	event-driven (daily checking)	event-driven (daily checking)	event-driven (daily checking)
Transport Flexibility	Availability of transport alternatives at short notice	no	no	no	no	no	no
	Latest possible time for placing transport order	≤ 1 week prior to shipping <sup>3</sup>	≤ 1 week prior to shipping <sup>3</sup>	≤ 1 week prior to shipping <sup>3</sup>	≤ 1 week prior to shipping <sup>3</sup>	≤ 1 week prior to shipping <sup>3</sup>	≤ 1 week prior to shipping <sup>3</sup>
	Transport vehicle ownership	long-term leasing	long-term leasing	long-term leasing	long-term leasing	long-term leasing <sup>4</sup>	long-term leasing
	Non-transport related measures for addressing demand deviations	many	many	many	many	many	many

<sup>1</sup> block trains for large customers (shipping-paid deliveries)

<sup>2</sup> institutionalized revision cycles; event-driven modifications are necessary too

<sup>3</sup> regular due date

<sup>4</sup> delegated to assigned freight railway

Fixed transport capacities also limit the maximum number of shipments at times of peak demand. This requires shippers to find other solutions for coping with peak demand. Transport flexibility is also limited by a lack of transport alternatives, as shipping large quantities of fuel and heating oil is financially unattractive by truck. Assigning several freight railways is possible but not common at analysed shippers within Switzerland.

The reduced flexibility of transport planning is compensated by numerous non-transport related measures for coping with demand deviations. This is possible because of the 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 [EZV (2010)]. This widely used possibility allows shippers' transport planning units 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, shipping companies may operate block trains as initially planned but with other goods (e.g. heating oil instead of fuel). For the large shippers 1 and 2, it is even possible to handle customer cancellations of ordered trains without changing transport plans. If these customers are using the same joint-venture distribution depots, already planned block trains can be used to supply the shipper's own storage capacities. In both cases, there is no change at transport plans necessary.

### 8.2.2.5 Provided Planning Output to Freight Railways

The results from the analyses of shipment orders and forecasts are summarised in Table 8-7. Only three out of the six analysed shippers provide forecasts to the freight railway and this on a voluntary and non-binding basis. Provided forecasts consistently have a high level of detail but differ in all other characterising forecast features. The consequence is an inhomogeneous and incomplete picture at the freight railway about the overall future transport demand in the mineral oil sector. Forecasts of shipper 1 are clearly the most valuable one. More than 75% of total shipments are forecasted and this with a very high accuracy of more than 90%. This shipper regularly provides forecasts at the end of each month for the entire upcoming month to the assigned freight railway<sup>59</sup>. The forecast horizon therefore covers one month at maximum. A monthly forecast frequency seems low. Yet, a higher frequency would provide little added value in the case of shipper 1, as the accuracy is already very high.

Compared to shipper 1, forecasts of shipper 5 are clearly of minor value. Forecasts are irregularly provided, which leads to a low coverage rate of predicted shipments<sup>60</sup>. Moreover, the accuracy is low, despite of a forecast horizon of 2-3 weeks only.

Shipper 6 consistently provides forecasts on a weekly basis, covering a time horizon of 2-3 weeks. This weekly frequency entails that already given forecasts are regularly updated. The accuracy is high with close to 90%.

**Table 8-7: Provided planning output to freight railway: results (1/2)**

<i>Feature</i>	<i>Shipper 1</i>	<i>Shipper 2</i>	<i>Shipper 3</i>	<i>Shipper 4</i>	<i>Shipper 5</i>	<i>Shipper 6</i>
Share of shipments forecasted	75% - 90%	0%	0%	0%	50% - 75%	> 90%
Forecast accuracy	> 90%	-	-	-	80% - 85%	85% - 90%
Forecast frequency	monthly <sup>1</sup>	-	-	-	irregular	weekly
Forecast time horizon	≥ 1 month <sup>2</sup>	-	-	-	2 - 3 weeks	2 - 3 weeks
Forecast level of detail	day	-	-	-	day	day
Order accuracy	> 95%	90% - 95%	> 95%	85% - 90%	90% - 95%	> 95%
Dominant type of change (forecasts and orders)	cancellation	cancellation	cancellation	change of destination	change of destination	cancellation

<sup>1</sup> some event-driven updates of monthly forecast during months

<sup>2</sup> maximal forecast horizon at the beginning of each month

The accuracy of weekly train orders is also differing between analysed shippers. Subsequent changes are nearly inexistent at shipper 1 with a percentage of less than 1%. In turn, orders of shipper 4 have an accuracy of around 88% only. Weekly train orders of the remaining four shippers show accuracies in the range of 93% and 98%. Cancellations are the common type of subsequent changes. For the large shippers 1 and 2, this type is

<sup>59</sup> This means that shipments in the first week of each month are not forecasted, which largely explains the partial forecast coverage rate of total shipments.

<sup>60</sup> As the procedure of transport planning does not change from week to week, there is actually no reason why forecasts are not regularly provided. These interruptions thus rather show a missing use of such data at the freight railway. Otherwise, the freight railway would insist on receiving them regularly.

clearly dominant with a share of more than 75%. Cancellations are also the most common type of subsequent changes at shippers 3 and 6, but changes of destination and shipping dates are almost equally frequent. For shippers 4 and 5, the most dominant type of subsequent changes is the change of destination. However, cancellations are highly relevant in those companies too with a share of around 40% on subsequent changes.

As only three out of the six analysed shippers provide forecasts to the freight railway, additional data analyses have been conducted with four other companies shipping mineral oil products in Switzerland. Their shipping volumes are comparable to those of shippers 5 and 6. The results are shown in Table 8-8.

**Table 8-8: Provided planning output to freight railway: results (2/2)**

<i>Feature</i>	<i>Shipper 7</i> <sup>1</sup>	<i>Shipper 8</i> <sup>1</sup>	<i>Shipper 9</i>	<i>Shipper 10</i>
Share of shipments forecasted	> 90%	> 90%	50% - 75%	< 50%
Forecast accuracy	> 90%	> 90%	< 80%	85% - 90%
Forecast frequency	monthly	monthly	weekly	irregular
Forecast time horizon	≥ 1 month	≥ 1 month	≥ 1 month <sup>2</sup>	2 - 3 weeks
Forecast level of detail	day	day	day	day
Order accuracy	> 95%	> 95%	90% - 95%	> 95%
Dominant type of change (forecasts and orders)	cancellation	cancellation	cancellation	change of date

<sup>1</sup> shipper with (jet) fuel transports only

<sup>2</sup> maximal forecast horizon at the beginning of each month

All four shippers provide shipment forecasts to the freight railway, yet again in an inhomogeneous way. Shippers 7 and 8 follow the same approach like company 1. The regularly provide forecasts at the end of each month for the entire upcoming month to the freight railway. In contrary to all other analysed shippers, they ship (jet) fuel only. The lack of heating oil apparently has a significant effect on both accuracy and share of shipments forecasted with values of each more 90%. However, shipper 1 proves that the reverse of this argument is not necessarily true.

Shipper 9 provides forecasts in a clearly systematic way to the freight railway. Submitted forecasts at the beginning of each month predict the entire month, while the weekly forecasts during month represent updates of the monthly prediction. The value of these forecasts is rather low, overall. Despite of regular forecast updates, only 60% of total shipments are forecasted. This means that many additional and unpredicted shipments are placed in final shipment orders. Second, the accuracy of forecasted shipments is low with a percentage of around 65%. At least, the accuracy of train orders is – as for the other shippers – consistently high with a figure of more than 90%.

Eventually, the forecast characteristic of shipper 10 is comparable with those of shipper 5. The forecast accuracy is quite high with close to 90%. However, only a third of total shipments are forecasted. This is partly explained by irregular forecast transmissions but also by the fact that many additional shipments are placed in final orders.

## 8.2.3 Evaluation

### 8.2.3.1 Provided Planning Output

The empirical analyses allow a number of general conclusions about submitted shipment orders and forecasts in the mineral oil sector:

- Small-size shippers tend to submit forecasts rather than larger ones. Remarkably, none of the analysed medium-size shippers provide forecasts. As a consequence, only a minority of total shipments are forecasted, although a majority of shippers provide forecasts to the freight railway.
- For those shippers providing forecasts, a great variety is noticed in both form and quality. This is partly explainable by the fact that their submission is neither standardised nor explicitly demanded by the freight railway today.
- The analysed data show, that accurate and detailed monthly forecasts are possible under certain conditions in the mineral oil sector. On the other end of the spectrum, one shipper is not even able to place accurate shipment orders.
- The analysis further reveals that forecast accuracies do not have to correlate with the forecast horizon.

Overall, the situation is unsatisfying for the freight railway. A majority of shippers from the mineral oil sector provide forecast information, but in differing quality and only representing a minority of overall shipments. This hinders the implementation of many collaborative approaches, identified in chapter 6. It is therefore essential to identify additional forecast potentials.

The following chapter is dedicated to approach this question. It discloses the reasons behind the individual forecasting behaviours of analysed shipping companies. Possible inconsistencies will help identify unused potentials, or – if there are not any – explain, why additional forecasts cannot be expected.

### 8.2.3.2 Discussion

The analysed shippers show broad similarities in terms of transport planning. Transport planning typically has a time horizon of one month, which is updated on an event-driven basis. The use of long-term leased rail tank wagons and – more important – a lack of transport alternatives at short-notice limit transport flexibility of shippers in the mineral oil sector of Switzerland. Stable transport plans are therefore in their very own interest. A decisive advantage is the fact that shippers from the mineral oil sector generally dispose of numerous non-transport related measures for coping with demand deviations. This is mainly enabled through statutory stockpiling requirements for mineral oil companies and the fact that mineral oil companies are basically trading identical products<sup>61</sup>.

---

<sup>61</sup> For details please refer to chapter 8.2.2.4.2

Differing characteristics are primarily found in the field of transport network and at transport origins/destinations. Five major differences have been identified between analysed companies, which apparently influence shipper’s ability to provide accurate forecasts (Table 8-9).

**Table 8-9: Differences in shippers’ characteristics and provided information**

Feature	large-size shippers		medium-size shippers		small-size shippers			
	Shipper 1	Shipper 2	Shipper 3	Shipper 4	Shipper 5	Shipper 6	Shipper 7	Shipper 8
Network extent	domestic / short-distance	domestic / short-distance	domestic / short-distance	international / long-distance	domestic / short-distance	domestic / short-distance		
Number of railways involved per transport	one	one	one	several	one	one		
Provider of shipping-paid deliveries	yes	yes	yes	yes	no	no		
User of shipping-paid deliveries	no	no	no	no	yes, partly	yes, partly		
Quantitative flexibility of production capacity at origin	not flexible in terms of time	not flexible in terms of time	-	not flexible in terms of time	-	-		
Inventory philosophy at origin	minimum inventory	minimum inventory	medium inventory	n/a	medium inventory	medium inventory		
Entity in charge of origin site	= freight payer	= freight payer	= freight payer	≠ freight payer	= freight payer	= freight payer		
Entity in charge of destination site	= freight payer	= freight payer	= freight payer	= freight payer	= freight payer	= freight payer		
Forecast technique (fuel)	mathematical	mathematical	mathematical	mathematical	mathematical	mathematical		
Forecast technique (heating oil)	intuitive	intuitive	intuitive	intuitive	intuitive	intuitive		
Share of shipments forecasted	75% - 90%	0%	0%	0%	50% - 75%	> 90%	> 90%	> 90%
Forecast accuracy	> 90%	-	-	-	80% - 85%	85% - 90%	> 90%	> 90%
Forecast frequency	monthly <sup>3</sup>	-	-	-	irregular	weekly	monthly	monthly
Forecast time horizon	≥ 1 month	-	-	-	2 - 3 weeks	2 - 3 weeks	≥ 1 month	≥ 1 month
Forecast level of detail	day	-	-	-	day	day	day	day
Order accuracy	> 95%	90% - 95%	> 95%	85% - 90%	90% - 95%	> 95%	> 95%	> 95%
Dominant type of change (forecasts and orders)	cancellation	cancellation	cancellation	change of destination	change of destination	cancellation	cancellation	cancellation

<sup>1</sup> a minority of origins are distribution depots with medium inventory and shared use of rail siding  
<sup>2</sup> majority of destinations  
<sup>3</sup> some event-driven updates of monthly forecast during month

not analysed

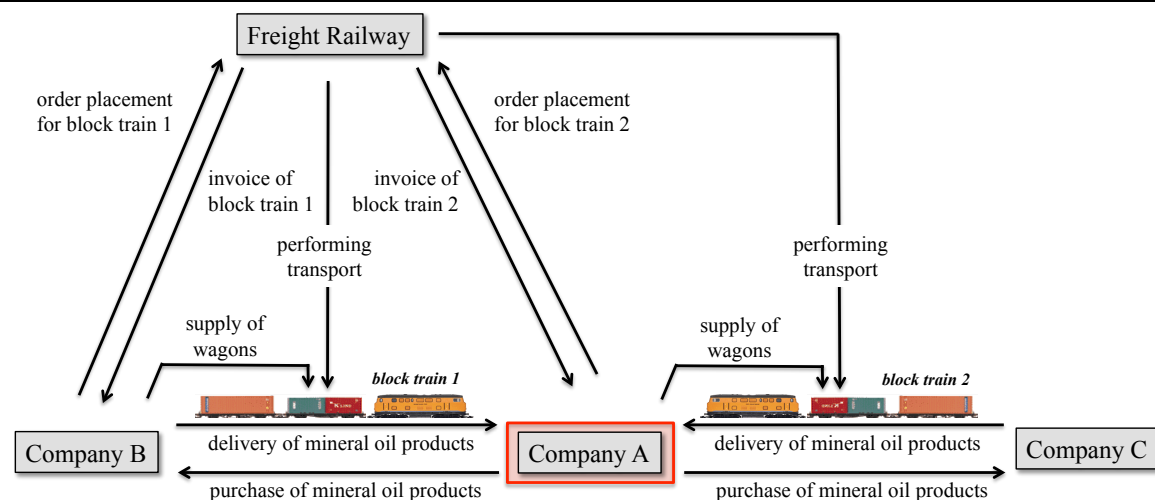
### 1) International rail transports with several freight railways involved

The shipper having the lowest order accuracy is concurrently the only one with international rail transports and several railways involved per transport. This correlation appears plausible. At first, it can be assumed that a low order accuracy is not in the intention of the shipper neither, as it disturbs its own vehicle schedules. The cause must therefore be externally. The more complex a rail transport network is, the more vulnerable it gets. Long-distance international transports with several freight railways generally have a higher chance of delays than domestic transports. A typical source of delays is the hand-over of trains from one carrier to the other at national borders. In this regard, the interviewed logistic planner of the respective shipper pointed out, that a single delay can lead to a cascade of transport planning modifications, because destinations of other trains have to be changed to ensure supplies of critical distribution depots.

### 2) Outsourcing of certain mineral oil transports to competitors

Small-size shippers of mineral oil products often outsource (parts of) their transports to medium- and large-size suppliers of mineral oil products. This means, they purchase heating oil and/or fuel from competitors, including its delivery to desired distribution depots. This opens opportunities for small-size shippers to diversify their rail transport strategy. This can lead up to an entire transport outsourcing to suppliers. Generally though, small mineral oil trading companies choose a hybrid of shipping-paid deliveries and rail transports in own responsibility. Figure 8-7 illustrates this strategy of partly outsourced rail transports in the mineral oil sector.

**Figure 8-7: Transport strategy with partly outsourced rail transports**



It can be economically useful for Company A to outsource rather uncertain block trains (“block train 1”) to Company B and to operate block trains for basic demand itself (“block train 2”). This has a stabilising effect on rail transports, which remain in the responsibility of Company A. However, the opposite effect is generated at Company B, taking over such outsourced transports. Its block trains tend to become less predictable. In reality, these are typically medium- and large-size shippers. In this regard, large-size shippers have a



certain advantage. If block train orders of mineral oil products are cancelled at short-notice, large-size shippers are rather able to leave planned block trains unchanged and use freed up transport capacities for supplying own depots.

### **3) Exclusive responsibility of distributing production output of refinery**

Being in the exclusive responsibility for distributing production output of a refinery apparently has a strong effect on the ability to provide accurate forecasts. This is the only reasonable explanation for the impressive forecast accuracy of shipper 1. The production output of a refinery is not flexible at short-notice and inventory is held at a minimum. These circumstances force transport-planning units to operate planned trains even though demand of heating oil and fuel is other than expected. This stabilising effect significantly increases the accuracy of rail transport planning and forecasts. Pure trading companies are more flexible to place extra shipment orders or postpone/cancel existing ones if demand develops differently than expected.

### **4) Full control of inventories at transport origin and destination through shipper**

Most non-transport related measures for coping with demand variations require that shippers control inventories at transport origins and destinations. This is mostly the case in the mineral oil sector of Switzerland. Nonetheless, slight differences are noticeable. While small-size companies always control their inventories at destination, it is only a majority for medium- and large-sized ones. This is caused by deliveries to storage depots of external customers.

Only shipper 4 does not control the origin of its transport. This company also shows the lowest order accuracy and provides no forecasts. Estimating the actual correlation is difficult however, as the shipper is concurrently the only one having an international network.

### **5) Pure fuel transports on rail**

While fuel demand is quite stable with known minor seasonality, demand of heating oil is highly volatile and difficult to predict. It is therefore not surprising that pure fuel shipping companies are able to provide very accurate forecasts for time periods of one month and more. Shippers 7 and 8 prove this correlation vividly. The contrary is not necessary true, however. An increasing share of heating oil in mineral oil transports indeed increases uncertainty for transport planning. The accuracy of transport forecasts therefore tends to deteriorate. However, the empirical results show that some mineral oil shippers are able to compensate this volatility without adjusting their rail transport planning (shipper 1).

## **8.2.3.3 Inconsistencies**

The identified five key influencing factors on the forecast ability of shipments reveal some inconsistencies between shippers and give hints for unused forecast potentials:

- There is a substantiate chance that shipper 2 is able to provide comparable shipment forecasts like shipper 1, as their characteristic are highly similar.

- Shipper 5 should be able to provide forecasts as regular as shipper 6. This would significantly increase shipper’s share of shipments forecasted.
- Comparably advantageous network characteristics and a very high order accuracy provide reasonable grounds to believe that shipper 3 is able to provide accurate forecasts, at least for a time horizon of two weeks. This in view of the fact, that shipper 3 is a medium-size shipper, generally having more difficulties for predicting rail transports accurately.

### 8.2.3.4 Conclusion

Taking the forecast potential of shippers 2, 3, and 5 into account, a large majority of shipments in the mineral oil sector is predictable. Small shipping companies clearly show that a time horizon of 2-3 weeks is generally the limit and that an average forecast accuracy between 80% and 90% must be accepted. Only a minority of shipments can be forecasted with a high accuracy of more than 90% over a time period of 2-3 weeks. Table 8-10 summarises these key results. It will serve as reference in chapter 9.1 to discuss the feasibility of collaborative approaches identified in chapter 6.

**Table 8-10: Forecast potential for rail transports in the mineral oil sector**

Feature		Value				Value				
Forecast potential	Accuracy	low	medium	high		low	medium	high		
	Share of total shipments <sup>1</sup>	minority		large majority		minority		large majority		
	Frequency	event-driven	monthly	weekly	daily	event-driven	monthly	weekly	daily	
	Time horizon	≤ 1 week	2 - 3 weeks		≥ 1 month		≤ 1 week	2 - 3 weeks		≥ 1 month
	Level of detail	week	day		hour		week	day		hour

**or**

<sup>1</sup> based on total transport volumes in transport sector

## 8.3 Gravel

### 8.3.1 Introduction

#### 8.3.1.1 Products

Gravel and sand belong to the class of detrital sedimentary rocks, together with mud [WICANDER AND MONROE (2006)]. Gravel and sand deposits are accumulations, which have been released from parent rocks by mechanical or chemical weathering. The varieties in this category are classified by the size of their constituent particles (Table 8-11). For simplicity reasons, this study will use the term “gravel” for all sand, pebble, and granule sediments.

**Table 8-11: Classification of detrital sedimentary rocks**

Sediment Name	Wentworth Class	Sizes [mm]
Gravel	Boulder	> 256
	Cobble	64 – 256
	Pebble	4 – 64
	Granule	2 – 4
Sand	(diverse)	1/16 – 2
Mud	(diverse)	< 1/16

Sources: WICANDER AND MONROE (2006) / WENTWORTH (1922)

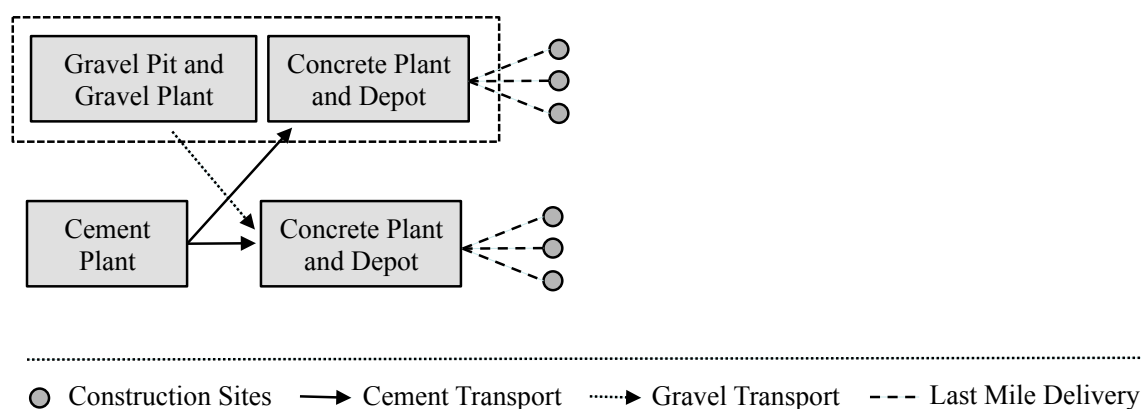
Most of produced gravel is used for concrete production and road construction [FSKB (2011)]. These categories generate significant rail transport volumes in Switzerland. Gravel transports are statistically recorded as mining and quarrying products in the standard classification system for goods (Table 2-1). Although gravel transports are not shown separately in official statistics, a qualified assumption is still possible:

The Swiss Federal Statistical Office (SFSO) indicates for mining and quarrying products a rail freight performance of 623 millions tons-km and a transport amount of 5.7 millions tons in 2010. In Switzerland, the large majority of gravel trains origin from gravel pits in the north of the canton of Zurich. It is further known that around 3 million tons of gravel and excavated material are annually shipped on rail in the canton of Zurich [AWEL (2011)]. The share of gravel on these transports was on average 56% between 2000 and 2003<sup>62</sup>. Hence, approximately 1.7 million tons of gravel is shipped on rail each year in the canton of Zurich. With the assumption that gravel transports from other destinations are negligible in Switzerland, the share of gravel in the official figures of SFSO for conveyed mining and quarrying products can be estimated to approximately 30%. This gives an annual rail freight performance of gravel transports of around 190 million tons-km. This is around 2% of total rail freight performance in Switzerland (Table 2-1).

### 8.3.1.2 Supply Chain Description

Gravel is excavated in gravel pits and processed on site in gravel plants (Figure 8-8). The outputs are different grades of aggregates for road construction and concrete production. Switzerland is a country with numerous and extensive deposits of gravel. Many concrete plants are therefore directly affiliated to a gravel pit and plant. Yet, some concrete plants and depots for road construction aggregates are supplied externally, making gravel transports necessary. Depending on the geographical location, transport volumes, and available infrastructure, rail is an attractive transport option. Last-mile deliveries to construction sites are generally done by truck.

<sup>62</sup> Response RR 445/2004 of the Zurich cantonal government concerning modal split of gravel and excavated material.

**Figure 8-8: Typical supply chain structures in the gravel industry**

Source: Author / based on FSKB (2011)

## 8.3.2 Empirical Results

### 8.3.2.1 Data Base

Three shippers of gravel were selected for analysing rail transport planning in this sector. Together, they are responsible for most of gravel transports on rail in Switzerland. The results from the analyses are therefore representative for Switzerland. The number of loaded trains per week and shipper varies between around 5 and 20.

The empirical research was conducted with guideline-based face-to-face interviews during 2011 with people being responsible for rail transport logistics at selected shippers. During interviews, additional materials were sometimes provided, such as company documents, reports, and presentation materials. The interview guideline was structured in four sections, which have been arranged in a time-logical order: basis for planning, transport planning procedure, forecast/order transferring, and short-term change management (Appendix E).

In addition, SBB Cargo provided real data from 2009 to analyse the accuracy of submitted train orders. No forecast information is submitted from shippers to the freight railway. The plausibility of the data analyses was subsequently checked with people being responsible for the operational planning of gravel trains at the freight railway.

The results of the qualitative interviews and quantitative transport data are comparable, despite of their time shift of two years. No significant change with relevance to transport planning has occurred between 2009 and 2011 (e.g. new order conditions or transport strategies).

### 8.3.2.2 Transport Logistic Organisation

The logistics network of gravel shippers in Switzerland is characterised by a single transport origin – generally located in the north of canton Zurich – and several transport

destinations (Table 8-12). This structure remains largely stable over the years. The percentage of transport volumes on top 20% of relations is between 50%-80% for shippers 1 and 3, and less than 50% for shipper 2. The latter is a sign of a quite uniform distribution of shipments on serviced relations. The transport network is limited to Switzerland, more precisely in the East and Central part of Switzerland. As a result, rail transport distances are rarely more than 100 km.

It is common practice in this sector that producers of gravel deliver their products shipping-paid to customers. All three analysed companies are therefore concurrently shipper and producer of gravel.

**Table 8-12: Transport network & responsibilities: results**

<i>Feature</i>	<i>Shipper 1</i>	<i>Shipper 2</i>	<i>Shipper 3</i>
Number of origins	1	1	1
Number of destinations	> 15	6 – 15	6 – 15
Transport volume on top 20% of relations	50% – 80%	< 50%	50% – 80%
Network extent	domestic / short-distance	domestic / short-distance	domestic / short-distance
Number of railways involved per transport	one	one	one
Provider of shipping-paid deliveries	yes	yes	yes
Enquirer of shipping-paid deliveries	no	no	no
Entity responsible for releasing products being shipped	= freight payer	= freight payer	= freight payer

The physical characteristic at transport origins and destinations strongly resemble between analysed shippers (Table 8-13). Transport origins are gravel pits with associated gravel plants. They are under direct control of the shipping companies as producers of those products. The production flexibility of both gravel pits and plants is high and adjustable on actual demand. This allows a just-in-time production, enabling minimal inventories at production site. However, the composition of produced gravel varies in terms of grain sizes and so do their individual inventories. It is therefore possible that inventories of some components are temporarily higher than others.

The majority of gravel transports are shipped to external customers. Shippers of gravel thus generally not control transport destination sites. At shippers 1 and 2, a minority of shipments is dedicated to supply in-house gravel demand for concrete plants and depots for road construction. However, even though these destination sites are formally in control of the shipping company, transport planners cannot really take advantage of it. This is because transport planning and inventory management are two different organisational units, acting largely independent from each other.

The production flexibility of concrete plants at transport destinations is well adjustable on actual demand. Further, there are only minimal inventories available to supply these plants with gravel. The same applies for material depots for road construction. As a

consequence, any variation in demand of concrete and road construction materials has an immediate and one-to-one effect on gravel demand.

**Table 8-13: Transport origin and destination: results**

	<i>Feature</i>	<i>Shipper 1</i>	<i>Shipper 2</i>	<i>Shipper 3</i>
<b>Transport Origin</b>	Quantitative flexibility of production capacity at origin	flexible in terms of time	flexible in terms of time	flexible in terms of time
	Inventory philosophy at origin	minimum inventory (just-in-time)	minimum inventory (just-in-time)	minimum inventory (just-in-time)
	Entity in charge of origin site	= freight payer	= freight payer	= freight payer
	Use of rail siding	exclusive	exclusive	exclusive
<b>Transport Destination</b>	Quantitative flexibility of production capacity at destination	flexible in terms of time	flexible in terms of time	flexible in terms of time
	Inventory philosophy at destination	minimum inventory (just-in-time)	minimum inventory (just-in-time)	minimum inventory (just-in-time)
	Entity in charge of destination site	≠ freight payer <sup>1</sup>	≠ freight payer <sup>1</sup>	≠ freight payer
	Use of rail siding	exclusive <sup>2</sup>	exclusive <sup>2</sup>	exclusive <sup>2</sup>

<sup>1</sup> majority of destinations

<sup>2</sup> with exceptions

At last, shippers of gravel generally use rail sidings exclusively at both transport origin and destination, giving them high flexibility for unloading and loading trains. In the few cases in which rail sidings are used by several shippers, the need for coordination remains little. Traffic volume is simply too low for that.

### 8.3.2.3 Sales Planning

On rail, gravel is exclusively shipped in block trains (Table 8-14). Minimum inventories at destination sites entail that delivery due dates are generally not flexible.

Sales planning is rudimentary at analysed shippers, if not missing at all. Long-term quantity contracts with customers of gravel provide an approximate range of annual shipping amounts per destination. During the year, complementing information is sometimes provided from customers about upcoming large phases of constructions, going along with increased demands of gravel. However, the reliability and level of detail of this information is mostly too low to be used for planning. Altogether, reliable sales plans do not exist until customers have placed their orders for gravel supply one week in advance. Even these short-term orders are based on an intuitive forecast of expected demand.

**Table 8-14: Sales planning: results**

	<i>Feature</i>	<i>Shipper 1</i>	<i>Shipper 2</i>	<i>Shipper 3</i>
	Shipment lot size	block trains	block trains	block trains
	Delivery date flexibility	not flexible	not flexible	not flexible
<b>Sales Plan</b>	Time horizon	≤ 1 week	≤ 1 week	≤ 1 week
	Level of detail	day	day	day
	Forecast technique	intuitive	intuitive	intuitive

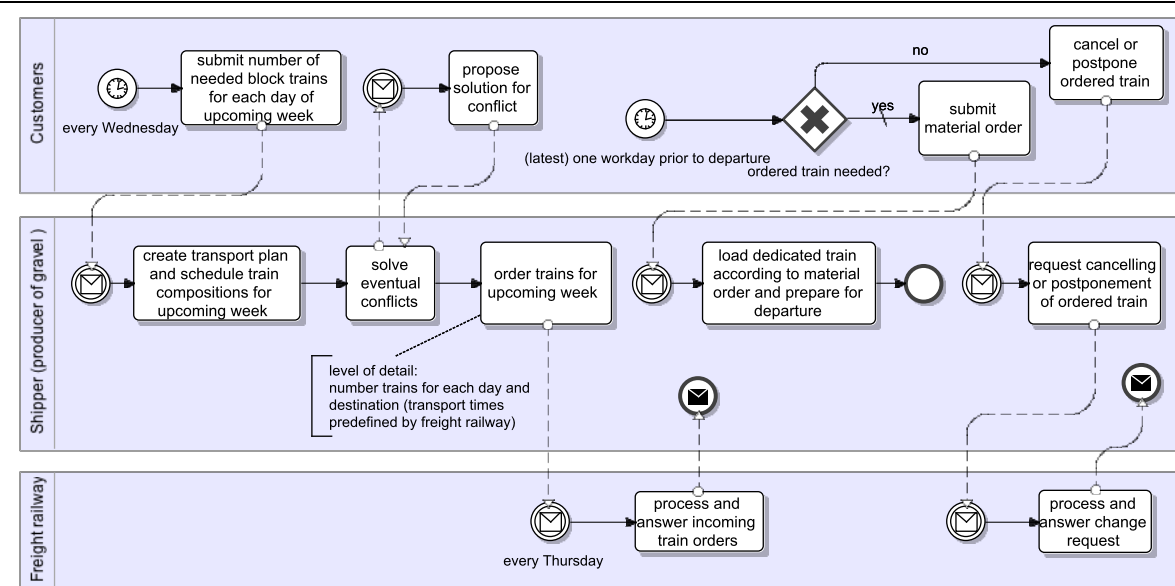
An important reason for rudimentary sales plans is the unpredictable and highly volatile demand on end-customer side, which is driven by construction activities. This sector shows a distinct seasonal demand pattern with significantly higher construction activities in summer than winter. Snow and ice not only slow down building activities during winter but can also hinder or even make impossible gravel transports at short-notice (risk of icing). Further, construction sites require complex logistics planning. Many working steps closely depend from each other. Delays in one activity can lead to numerous shifts at subsequent works. The fact that rain and other unfavourable weather conditions have a significant impact on the construction progress makes logistics planning further susceptible to short-term adaptations. Demand of construction aggregates may therefore rapidly change from one day to the other.

### 8.3.2.4 Transport Planning

#### 8.3.2.4.1 Process

Figure 8-9 depicts the typified planning process for rail-based gravel transports in Switzerland. Every Wednesday, shippers of gravel receive the number of expectedly needed trains for the upcoming week from their customers (buyers of gravel). As buyers of gravel do not yet have firm orders from their own customers, they are forced to estimate the potential gravel demand, taking into account current progress at supplied large construction sites, expected weather conditions and typical seasonal demand.

**Figure 8-9: Typified planning process of gravel transports on rail**



On this basis, shippers create weekly transport plans and schedule own train compositions. If incoming orders exceed transport capacities, selected customers are contacted to postpone or to cancel requested gravel trains. Transport planners only have few hours to create the weekly transport plan, as it must be submitted to the assigned freight railway on Thursday noon at latest.

Latest one workday prior to departure, customers of shippers submit the exact material composition (sand, pebble, granule) for ordered gravel trains. Shippers accordingly load and prepare these trains for departure. In case of insufficient inventory capacities, customers also have the possibility to cancel or – if possible – postpone ordered gravel trains latest one workday in advance at shippers.

#### 8.3.2.4.2 Characteristics

Table 8-15 shows the basis characteristics of rail transport planning in the gravel sector.

**Table 8-15: Transport planning: results**

<i>Feature</i>	<i>Shipper 1</i>	<i>Shipper 2</i>	<i>Shipper 3</i>
Time horizon	≤ 1 week	≤ 1 week	≤ 1 week
Level of detail	day	day	day
Revision cycle	event-driven	event-driven	event-driven
Availability of transport alternatives at short notice	yes	yes	yes
Latest possible time for placing transport order	≤ 1 week prior to shipping	≤ 1 week prior to shipping	≤ 1 week prior to shipping
Transport vehicle ownership	proprietary possession	proprietary possession	proprietary possession
Non-transport related measures for addressing demand deviations	none	none	none

The time horizon of operational rail transport planning is no longer than around one week in the gravel sector. These transport plans are based on estimated numbers of gravel trains from their customers and subject of frequent event-driven modifications at short-notice.

The analysed shippers operate freight wagons in proprietary possession<sup>63</sup>. Therefore, they have an immediate financial interest to maximize their utilisation. This requires regular and equally distributed shipments, which is highly congruent with interests of the freight railway.

However, translating this objective into reality is difficult. First and foremost, road competition is strong and highly flexible. Road-based deliveries of gravel are often possible within hours. In return, freight railways ship large amounts of heavy products more efficient than trucks, giving them a financial advantage. A significant shift from rail to road of gravel transports is not to be expected on existing relations. However, numerous gravel pits throughout the country provide attractive nearby alternatives for buyers of gravel, if transport conditions on rail decrease. The negotiating position for demanding stable and equally distributed train orders is consequently low for shippers of gravel.

<sup>63</sup> The geographical proximity of shippers' transport origins allows leasing freight wagons from each other. Despite of generally correlating transport demands, this form of collaboration gives shippers some flexibility to adjust transport capacities on actual demand.



Eventually, shippers in the gravel sector have no measures available for addressing demand variations without affecting planned rail transports. This makes gravel transports on rail susceptible for modifications.

### 8.3.2.5 Provided Planning Output to Freight Railway

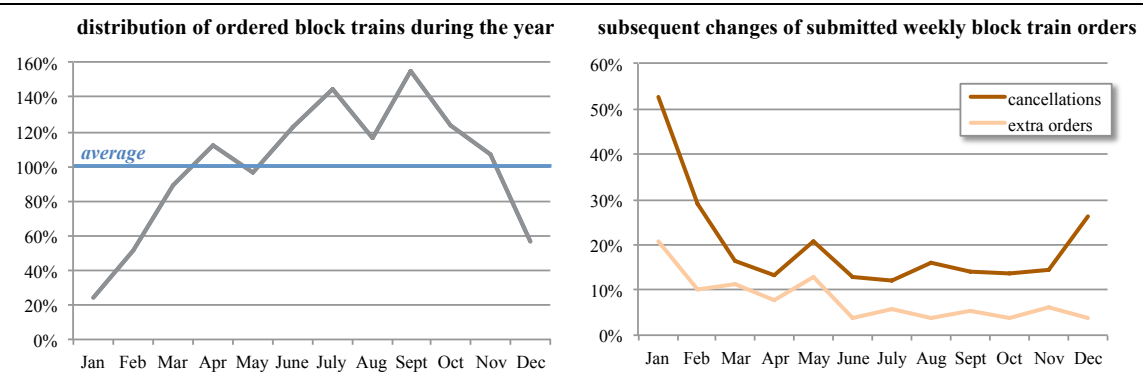
None of the three shippers provide forecast information to the assigned freight railway (Table 8-16). This appears comprehensible if one considers that even submitted shipment orders remain inaccurate with values clearly below 85%.

**Table 8-16: Provided planning output to freight railway: results**

<i>Feature</i>	<i>Shipper 1</i>	<i>Shipper 2</i>	<i>Shipper 3</i>
Share of shipments forecasted	0%	0%	0%
Forecast accuracy	-	-	-
Forecast frequency	-	-	-
Forecast time horizon	-	-	-
Forecast level of detail	-	-	-
Order accuracy	< 85%	< 85%	< 85%
Dominant type of change (forecasts and orders)	cancellation	cancellation	cancellation

Figure 8-10 shows additional data analyses from the analysed three shippers. First, there is an obvious and pronounced seasonality in the gravel sector. In 2009, over six times more trains were ordered in September than January. The number of shipments varies with rates of up to 50% from one month to the other. Further, the subsequent cancellation rate of placed train orders shoots upwards from December to February.

**Figure 8-10: Analysis of gravel shipments on rail in Switzerland**



Data: SBB Cargo; 2009

### **8.3.3 Evaluation**

#### **8.3.3.1 Provided Planning Output**

The empirical analyses allow a number of general conclusions about submitted shipment orders and forecasts in the gravel sector:

- The gravel sector currently provides no shipping forecasts, exceeding a weekly time horizon.
- The accuracy of submitted weekly shipment orders is low due to frequent subsequent cancellations and extra orders.
- Shipment orders for gravel transports follow a clear seasonality with pronounced peak demands in summer and low demands in winter. This justifies statements of interviewed experts.
- During wintertime, the cancellation rate of placed train orders is up to three times as high than on average. This confirms qualitative statements from interviewed experts indicating a significant influence of bad weather conditions on transportation, such as snow and ice.
- There is no difference in type and quality of submitted planning output between shipping companies in the gravel sector

#### **8.3.3.2 Discussion**

The characteristics of all three shippers are largely congruent, giving no hints for potential inconsistencies.

A detailed view on the characterising features shows that the general conditions for stable and far-reaching transport planning are in sum highly negative (Table 8-17).

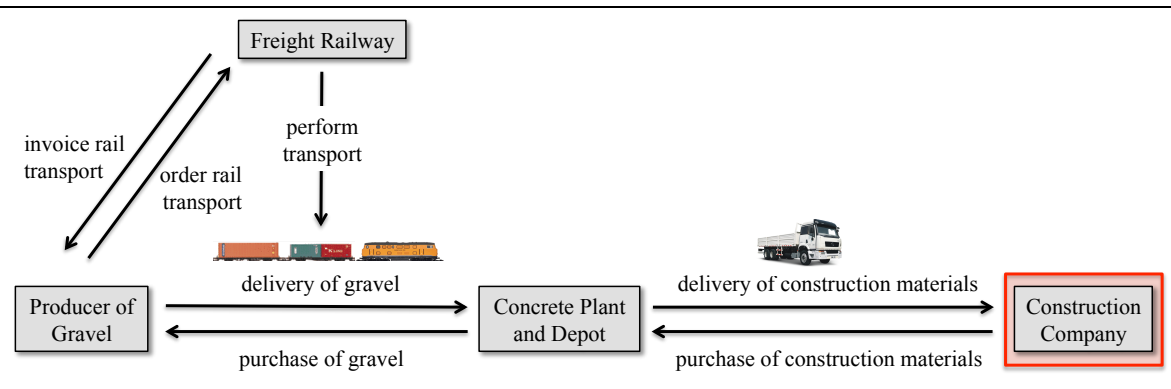
**Table 8-17: Reasons for missing forecasts and low order accuracies**

Feature		Shipper 1	Shipper 2	Shipper 3	
Sales Plan	Time horizon	≤ 1 week	≤ 1 week	≤ 1 week	1 volatile and unpredictable demand on end-customer side
	Level of detail	day	day	day	
	Forecast technique	intuitive	intuitive	intuitive	
Quantitative flexibility of production capacity at origin		flexible in terms of time	flexible in terms of time	flexible in terms of time	2 flexible production capacities
Quantitative flexibility of production capacity at dest.		flexible in terms of time	flexible in terms of time	flexible in terms of time	
Inventory philosophy at transport destination		minimum inventory (just-in-time)	minimum inventory (just-in-time)	minimum inventory (just-in-time)	3 missing buffer
Inventory philosophy at transport origin		minimum inventory (just-in-time)	minimum inventory (just-in-time)	minimum inventory (just-in-time)	
Delivery date flexibility		not flexible	not flexible	not flexible	
Non-transport related measures for addressing demand deviations		none	none	none	
Provider of shipping-paid deliveries		yes	yes	yes	4 dependency on shippers' customers to change situation
Entity in charge of destination site		≠ freight payer <sup>1</sup>	≠ freight payer <sup>1</sup>	≠ freight payer	
Availability of transport alternatives at short notice		yes	yes	yes	5 little willingness to change situation
Share of shipments forecasted		0%	0%	0%	
Forecast accuracy		-	-	-	
Forecast frequency		-	-	-	
Forecast time horizon		-	-	-	
Forecast level of detail		-	-	-	
Order accuracy		< 85%	< 85%	< 85%	
Dominant type of change (forecasts and orders)		cancellation	cancellation	cancellation	

<sup>1</sup> majority of destinations

**1) Volatile and unpredictable demand on end-customer side**

Construction companies – being the last and decisive element in the logistic chain of gravel – primarily determine demand of gravel (Figure 8-11). Activities in the building sector are highly volatile and so is their demand of construction materials. Numerous factors make it very difficult to determine daily demand (chapter 8.3.2.3). As a result, supplying companies like concrete plants grant lead times for material orders of one day or even less. Such companies thus have no reliable basis to predict their demand of gravel. Even their weekly orders to shippers of gravel are estimations only and subject of possible subsequent changes. Every prediction of sales demand exceeding this weekly time horizon would be even less reliable.

**Figure 8-11: Source of volatile and unpredictable gravel demand**

## 2) Flexible production capacities

Highly flexible production capacities at both concrete and gravel plants allow adjusting production output according to actual demand. Even short-term order request can be produced in time.

## 3) Missing buffer

As production capacities are able to produce nearly any demand within the requested lead-time, buffers are reduced to a minimum. Demand changes at end-customer side therefore immediately affect the entire logistic chain and usually allow no flexibility in delivery due dates. In contrary to the mineral oil sector, there are also no non-transport related measures available to manage demand variations without affecting transport plans.

Moreover, the combination of flexible production capacities and missing buffers increases fluctuation in demand for shippers of gravel at the beginning of the logistic chain. This is because individual demand variations in construction industry sum up due to mutual influencing factors (e.g. weather). This is not critical for the production of gravel, as their quantitative flexibility is high enough. Disadvantages face transport planning units at gravel shippers and notably the assigned freight railway. Both are forced to keep up with granted order flexibility on end-customer side and the ability of involved actors to produce Just-in-Time.

## 4) Dependency on shippers' customers to change situation

If shippers of gravel want to make their rail shipments more stable and predictable, they largely depend on their external customers. They control destination sites of rail transports and determine the number and date of transports. There are only few intra-company transports in the gravel sector. Even then, inventory and transports are independently planned and managed.

## 5) Little willingness/ability to change situation

Buyers of gravel have little reason to change current situation. First, road-based shippers are generally able to take on at least parts of rail transports, if transport conditions on rail decrease. Even missing road-based alternatives for certain transport destinations do not

necessarily open up leeways for more stable rail transport plans, e.g. through an increase of inventory capacities. Concrete plants and depots, being supplied with gravel by rail, are in strong competition with those being supplied by road. Logistics chains with pure road transports are apparently able to provide demanded flexibility and transport prices with minimum inventories and short lead times. Producers of gravel with rail based deliveries are therefore not in the position to change current practice without losing transport volumes.

### 8.3.3.3 Conclusion

There is no apparent forecast potential in the gravel transport sector, exceeding a weekly time horizon. Even this period is subject to major uncertainty. Involved actors in the rail-based logistic chain of gravel transports – freight railway, shipper (producer) and buyer of gravel – are not in the position to change existing market forces, which are largely driven by the construction industry.

Table 8-18 summarises this key result. It will serve as reference in chapter 9.1 to discuss the feasibility of collaborative approaches identified in chapter 6.

**Table 8-18: Forecast potential for rail transports in the gravel sector**

<i>Feature</i>		<i>Value</i>			
Forecast potential	Accuracy	low	medium	high	
	Share of total shipments <sup>1</sup>	minority		large majority	
	Frequency	event-driven	monthly	weekly	daily
	Time horizon	≤ 1 week	2 - 3 weeks		≥ 1 month
	Level of detail	week	day		hour

<sup>1</sup> based on total transport volumes in transport sector

## 8.4 Steel

### 8.4.1 Introduction

#### 8.4.1.1 Products

The word “steel” describes a great variety of workable iron alloys. It is defined as a material whose mass fraction of iron is greater than that of any other element and whose carbon content is lower than 2% [LAUTENSCHLÄGER ET AL. (2005)].

There are two basic processes for producing steel [CHEREMISINOFF (2003)]:

- *from iron ore*: heating of iron ore, coke and limestone in blast furnaces to obtain molten pig iron, in which high purity oxygen is injected.
- *from steel scrap*: smelting of steel scrap in electric arc furnace.

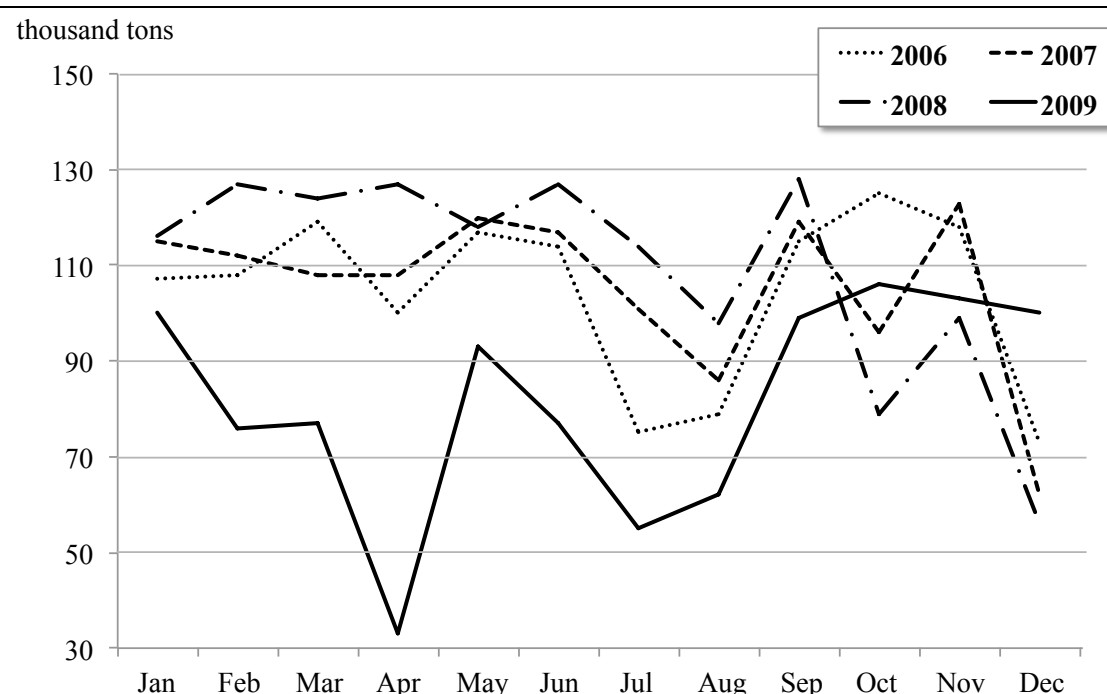
In Switzerland, steel is entirely produced from steel scrap. This is not surprising, as Switzerland is short of raw materials. A dense network of collection points, scrap

processors and traders ensure the recycling of this valuable secondary raw material. Steel scrap is not a uniform commodity: up to 24 different grades of steel scrap are accepted at steel mills [VSSV (2011)].

There are two steel mills in Switzerland. Together they produce about 1.4 million tons each year, of which approximately 400'000 tons are sold within Switzerland [SSHV (2011-1)]<sup>64</sup>. Swiss steel mills primarily produce long steel products, such as structural steel, free-cutting steel, or reinforcing steel<sup>65</sup>. A significant part of this output is delivered by rail.

The steel industry is traditionally driven by macroeconomic boom and bust cycles. As shown in Figure 8-12, steel production in Switzerland is also subject to significant monthly volatility and distinct seasonal lows in August and December<sup>66</sup>.

**Figure 8-12: Monthly steel production in Switzerland**



Source: SSHV (2011-2)

Around one million tons of steel scrap is generated each year in Switzerland. A large part of it is recycled in the two steel mills in Switzerland, which are supplied by rail to 70% - 75%<sup>67</sup>.

<sup>64</sup> In addition, 20 iron and steel foundries produce about 75,000 tons of casting each year in Switzerland. They are not considered in this study due to their comparatively negligible transport volumes.

<sup>65</sup> For more details please visit the company websites of Swiss Steel and Stahl Gerlafingen.

<sup>66</sup> The world economic crises led to a sharp drop in steel demand at the beginning of 2009 and disturbed common seasonality.

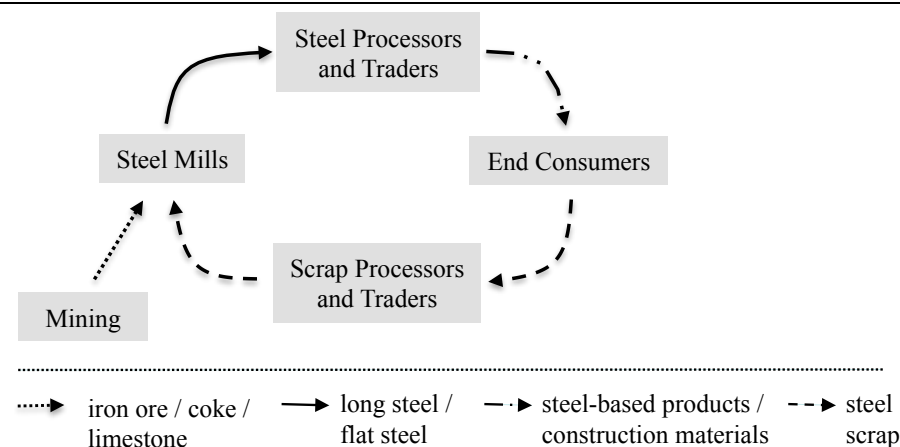
<sup>67</sup> Statement of Stahl Gerlafingen on company website (2011); Statement of Swiss Steel in SBB Cargo Magazin 04/07

Rail performances of domestic steel and steel scrap transports are not determinable from public figures. They are statistically recorded in the categories “basic metals and fabricated metal products” respectively “secondary raw materials and wastes”. For these two categories, the Swiss Federal Statistical Office indicates a rail freight performance of 785 millions tons-km in 2010, which is 7.3% of total rail freight performance (Table 2-1). The author of this study assumes that around 30% of this performance is generated by shipments from and to Swiss steel mills. The remaining 70% is the result of transiting steel transports, aluminium transports or non-metallic waste transports.

### 8.4.1.2 Supply Chain Description

Figure 8-13 depicts a typical supply chain in the steel industry. Mining industry and scrap processors/traders supply steel mills with primary raw materials (iron ore, coke, limestone) and secondary raw materials (steel scrap). In the case of Switzerland, steel mills are exclusively supplied by secondary raw materials. Supplying transports to steel mills are typically rail-based, due to the high weight of goods.

**Figure 8-13: Supply chain structure in the steel industry**



Source: Author / based on SSHV (2011-1)

The output of steel mills – long and flat steel – is delivered to steel processors<sup>68</sup> and traders, which again sell their products to end customers. The materials cycle is closed, when scrap processors and traders collect and sort accrued steel scrap from end consumers and sell it again to steel mills.

## 8.4.2 Empirical Results

### 8.4.2.1 Data Base

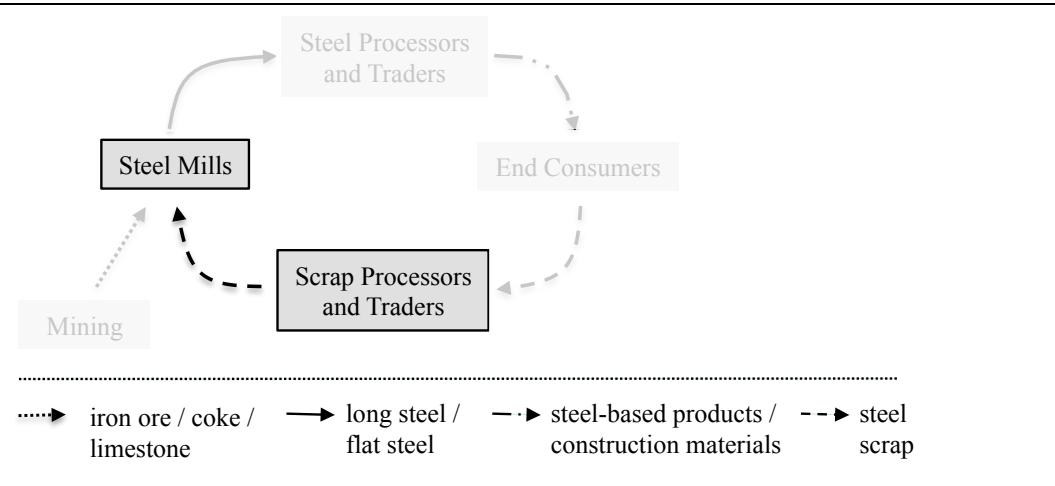
The two Swiss steel mills were selected to analyse rail transport planning in the steel sector of Switzerland. Together, they largely dominate the Swiss steel industry.

<sup>68</sup> Major steel processors are found in the automotive and machine industry.

In the course of research, it has become evident that a generalized description of transport planning processes for steel products is not feasible. Each product shows strongly differing influencing factors, notably with regards to sales planning. This required individual analyses for each product family of analysed companies, which would lead to highly company related conclusions. This contradicts the general character of this study with a preferably high transferability of results. Transport planning of long and flat steel products from steel mills were therefore not analysed any further.

In contrary, steel scrap is a commodity with similar determining factors concerning transport planning. Reliable statements and general conclusions are thus possible, despite of the small empirical sample of just two companies. This is because these companies act as freight payers for nearly all rail transports of steel scrap, which have their destination in Switzerland. The following analyses will therefore concentrate on rail transport planning of steel scrap to steel mills (Figure 8-14).

**Figure 8-14: Analysed rail transports in the steel industry**



The empirical research was conducted with guideline-based face-to-face interviews during 2010 with people being responsible for the rail transport logistics at the selected companies. The interview guideline was structured in four sections, which have been arranged in a time-logical order: basis for planning, transport planning procedure, forecast/order transferring, and short-term change management (Appendix E). In addition, personal interviews with people from the sales department of SBB Cargo were conducted to complement and discuss gathered information from shippers.

SBB Cargo also provided transport data from 2009 to analyse transport flows of steel and steel scrap transports, which have their origin and/or destination in Switzerland. Submitted forecast data from shippers do not exist. There was no significant change with relevance to operational transport planning between 2009 and 2010. Qualitative interviews are therefore comparable with provided quantitative transport data.



### 8.4.2.2 Transport Logistic Organisation

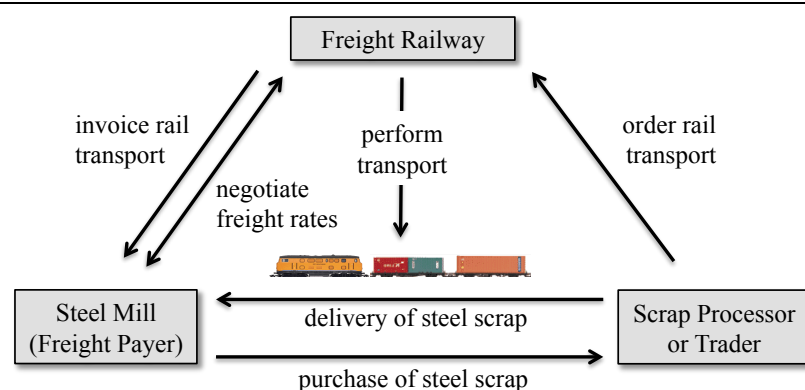
The logistics network for steel scrap supply is characterised by a single transport destination – the steel mills – and numerous transport origins, reflecting the large number of steel scrap suppliers (Table 8-19). The percentage of transport volumes on top 20% of relations is in the range of around 60%. This is a sign of a quite uniform distribution of shipments over the logistics network. The network of steel scrap transports is limited to Switzerland. As a result, rail transport distances are typically below 200 kilometres.

**Table 8-19: Transport network & responsibilities: results**

<i>Feature</i>	<i>Freight Payer 1</i>	<i>Freight Payer 2</i>
Number of origins	> 15	> 15
Number of destinations	1	1
Transport volume on top 20% of relations	50% – 80%	50% – 80%
Network extent	domestic / short-distance	domestic / short-distance
Number of railways involved per transport	one	one
Provider of shipping-paid deliveries	no	no
Enquirer of shipping-paid deliveries	no	no
Entity responsible for releasing products being shipped	≠ freight payer	≠ freight payer

Transport responsibility between buyer and seller of steel scrap is rather unusual (Figure 8-15). In Switzerland, steel mills are freight payers for all their supplying steel scrap shipments on rail. These aggregated large transport volumes generate a higher negotiation power towards the assigned freight railway, than if every steel scrap supplier would do that on its own. Interestingly however, scrap processors and traders remain the responsible entities for releasing steel scrap shipments to steel mills. In concrete terms, scrap processors and traders are free to determine when and in which lot sizes they provide steel mills with agreed monthly steel scrap quantities. Steel mills thus have no control over incoming steel scrap shipments, which they are paying for<sup>69</sup>.

<sup>69</sup> As a consequence, analysed companies do not entirely comply with the definition of “shipper” in Appendix F. Instead, the more appropriate term “freight payer” is used.

**Figure 8-15: Responsibilities in rail transports of steel scrap in Switzerland**

The physical characteristic at transport origins are characterised by medium inventories and are under control of the steel scrap processor or traders (Table 8-20).

At transport destination, the quantitative flexibility of steel production capacities is hardly flexible in terms of time. The continuous operation of installed furnaces is economically necessary, even at weekends. Furthermore, there are high inventories (heaps) of steel scrap at transport destination.

**Table 8-20: Transport origin and destination: results**

	<i>Feature</i>	<i>Freight Payer 1</i>	<i>Freight Payer 2</i>
<b>Transport Origin</b>	Inventory philosophy at origin	medium inventory	medium inventory
	Entity in charge of origin site	≠ freight payer	≠ freight payer
	Use of rail siding	exclusive	exclusive
<b>Transport Destination</b>	Quantitative flexibility of production capacity at destination	hardly flexible in terms of time	hardly flexible in terms of time
	Inventory philosophy at destination	high inventory	high inventory
	Entity in charge of destination site	= freight payer	= freight payer
	Use of rail siding	exclusive	exclusive

### 8.4.2.3 Procurement Planning

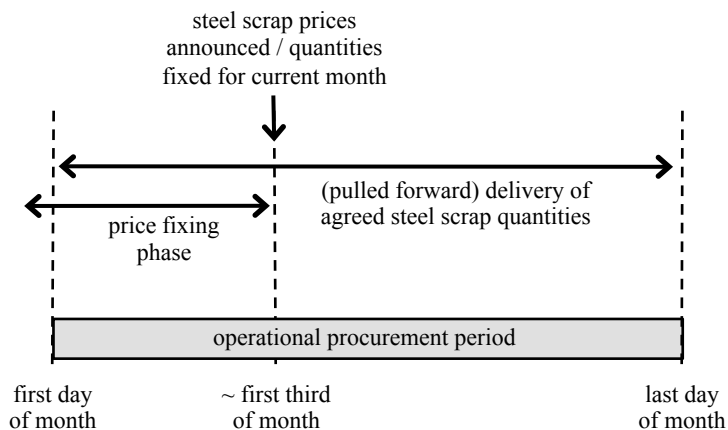
The minimal lot size for steel scrap shipments is one freight wagon (Table 8-21). Certain shipments may comprise several freight wagons, but clearly remain below the number for justifying block trains as standard shipment lot size. As a direct consequence, steel scrap is typically transported in the Swiss single wagonload network.

**Table 8-21: Procurement planning: results**

<i>Feature</i>		<i>Freight Payer 1</i>	<i>Freight Payer 2</i>
Shipment lot size		freight wagons	freight wagons
Delivery date flexibility		± 1 week or more	± 1 week or more
Procurement Plan	Time horizon	≥ 1 month	≥ 1 month
	Level of detail	month	month
	Forecast technique	intuitive	intuitive

Steel mills grant suppliers of steel scrap a high flexibility for delivery. While the monthly amount of steel scrap is agreed by contract, it is up to the supplier of steel scrap, at which dates and in which frequency he delivers.

The operational procurement plan of steel scrap is monthly elaborated. Knowing the basic procedure behind is essential to understand its significant effect on transport flows and planning (Figure 8-16).

**Figure 8-16: Basic procedure of steel scrap procurement**

The price fixing phase for steel scrap starts at the end of each month. It takes into account numerous factors such as planned steel production, recovered own steel scrap, and price notations in Switzerland as well as surrounding countries. The latter requires at least partly intuitive forecast techniques. Thanks to large inventories, procurement amounts of steel scrap do not necessarily correlate with steel production demand. If economically reasonable, steel scrap inventories are build-up or reduced. Steel scrap prices are announced to suppliers in the first third of the month, on which basis supplying monthly quantities are negotiated. Both price and quantities are retroactively valid for the entire month. If steel mills set monthly prices for steel scrap too low, they will not get needed amounts within Switzerland. This can make the procurement of steel scrap in surrounding countries necessary, which is often more expensive.

In practice, some suppliers already ship steel scrap to steel mills without yet knowing the actual price. Reasons can be the anticipation of assumingly high steel scrap prices but also a lack of alternatives.

This remarkably comfortable situation for suppliers of steel scrap is possible because steel scrap trade is a typical sellers' market in Switzerland. This puts steel scrap processors and traders in a strong position towards steel mills. According to interviewed experts, this situation is generated by the fact that steel scrap prices in Switzerland are still a little lower than in surrounding countries<sup>70</sup>. Steel mills thus walk on a fine line to offer prices and conditions, which prevents Swiss steel scrap processors and traders to export their products.

#### 8.4.2.4 Transport Planning

The above described transport responsibilities for steel scrap shipments entails that steel mills – being the freight payer and sole contact of the freight railway – perform no operational transport planning at all. Transport planning is in the responsibility of the suppliers of steel scrap, even though they do not (directly) pay induced shipments.

Although no personal interviews have been conducted with steel scrap processors and traders, gathered information nevertheless allows a qualified assumption (Table 8-22).

Transport planning is basically a day-to-day activity with a time horizon of few days only. This is possible because single wagonload service allows short-term placements of transport orders with no quantity constraints [SBB CARGO (2011)]. This high transport flexibility is reinforced by other factors: Although steel scrap is well suited to be carried on rail, road-based transports are nevertheless a feasible option in many cases. Further, there are little constraints regarding transport capacities for suppliers of steel scrap. Freight wagons are leased ad-hoc from the assigned freight railway. Such wagon orders are possible until one workday prior to departure.

**Table 8-22: Transport planning: results**

<i>Feature</i>	<i>Suppliers of steel scrap</i>
Time horizon	≤ 1 week <sup>1</sup>
Level of detail	daily <sup>1</sup>
Revision cycle	event-driven <sup>1</sup>
Availability of transport alternatives at short notice	yes <sup>1</sup>
Latest possible time for placing transport order	≤ 1 day prior to shipping
Transport vehicle ownership	ad-hoc leasing
Non-transport related measures for addressing demand deviations	none <sup>1</sup>

**Note:**  
There is no transport planning on freight payer's side.  
Suppliers of steel scrap release and plan rail shipments independently.

<sup>1</sup> qualified assumption

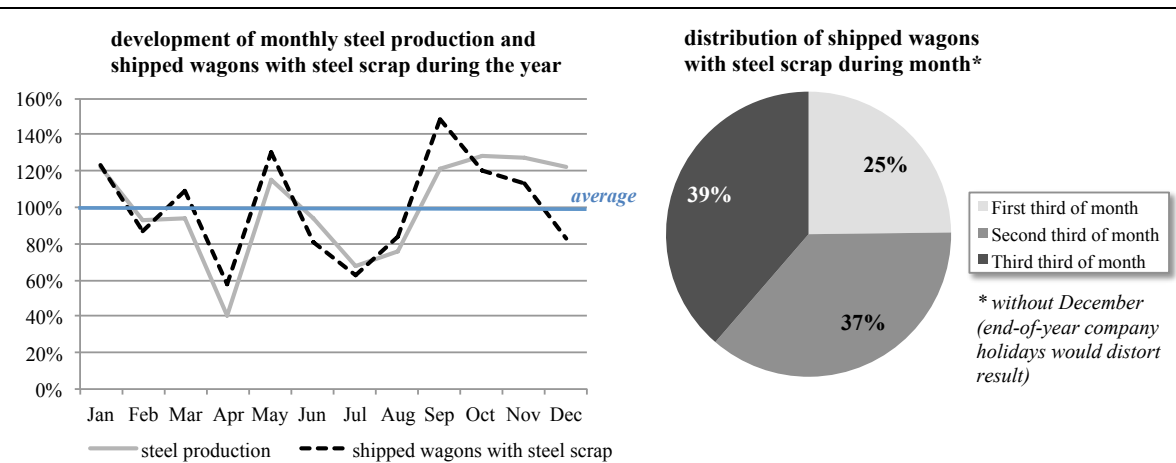
<sup>70</sup> Statement from 2010

### 8.4.2.5 Provided Planning Output to Freight Railway

The freight payer (= steel mill) provides no information about steel scrap transports to the freight railway because he simply does not have any. In contrary, the freight railway even has a slight information advantage. If a steel scrap supplier orders a wagon or places a transport order, it is the freight railway, which knows first about. Special access authorizations enable steel mills to check in freight railway's production system, how many steel scrap shipments are currently on the way. Steel mills therefore only know a few days in advance the number of wagons with steel scrap, which will arrive at production site.

Figure 8-17 shows some quantitative results about rail shipments of steel scrap to Swiss steel mills. First, the monthly distribution of shipped wagons strongly varies over the year. Monthly deviations of up to  $\pm 40\%$  from average are noticeable. Further, there is an evident – and plausible – correlation between shipped wagons of steel scrap and steel production. Significant deviations are nonetheless detectable in certain months like August and December. Second, the average distribution of shipped wagons with steel scrap during month shows a clear tendency of increasing transport volumes towards the end of each month. 39% of all wagons are shipped to steel mills within the last 10 days of the month, whereas this figure is at 25% for the first 10 days of month only.

**Figure 8-17: Analysis of steel scrap shipments on rail in Switzerland**



Data: SBB Cargo; SSHV (2011-2); figures from 2009

## 8.4.3 Evaluation

### 8.4.3.1 Provided Planning Output

The empirical analyses allow a number of general conclusions about submitted shipment orders and forecasts in the steel scrap sector:

- No forecasts about steel scrap shipments are provided to the freight railway.
- Shippers of steel scrap profit from granted flexibility in single wagonload service by placing transport orders at very short-notice.

- Rail shipments of steel scrap strongly vary between months. These fluctuations largely correlate with steel production volumes, being the major driver for shipments of steel scrap. Significant deviations between steel production and steel scrap supply are nonetheless noticeable. This confirms the existence of large steel scrap inventories at steel mills.
- Steel scrap shipment increase towards the end of month. A correlation with applied procurement practice is thereby apparent (Figure 8-16). Apart from that, no consistent pattern is discernible. This implies an uncoordinated delivery of steel scrap to steel mills.

#### **8.4.3.2 Discussion**

The situation appears contradictory in the steel scrap transport sector of Switzerland. On the one hand, basic conditions for accurate transport plans and forecasts are advantageous. On the other hand, no transport plans are available at freight payers in practice. Numerous factors explain this constellation (Table 8-23):

Indeed, steel scrap demands are difficult to predict from one month to the other. International price notations for steel scrap and steel production are too uncertain for that. However monthly delivered quantities are fixed after the first third of each month. This gives a time period of about 20 days, in which aggregated quantities of steel scrap supplies are known exactly. Significant buffer inventories at both transport origin and destination principally allow constant transport flows even if the gathering and use of steel scrap differs within this time. The chance of flexible delivery due dates for steel scrap can be used in different ways for transport planning. Today, it gives suppliers of steel scrap the possibility to ship their products whenever they want. For one, this makes the creation of transport plans largely superfluous. For another, the loading process of freight wagons can well consider needs of internal processes. Principally though, flexible delivery due dates for steel scrap could also be used for creating early and accurate transport plans, which respect the interests of steel mills, freight railways, and suppliers of steel scrap.

**Table 8-23: Reasons for contradicting situation in the steel scrap transport sector**

<i>Feature</i>		<i>Freight Payer 1</i>	<i>Freight Payer 2</i>	
Procurement Plan	Time horizon	≥ 1 month	≥ 1 month	Fixed monthly amount of steel scrap supplies after first third of month
	Level of detail	month	month	
	Forecast technique	intuitive	intuitive	
Inventory philosophy at transport origin		medium inventory	medium inventory	Significant buffer inventory at transport origin and destination
Inventory philosophy at transport destination		high inventory	high inventory	
Delivery date flexibility		± 1 week or more	± 1 week or more	Full flexibility for delivery of steel scrap within month
<b>Advantageous conditions for accurate transport plans and forecasts</b>				
<b>No transport plans available at freight payers</b>				
Entity responsible for releasing products being shipped		≠ freight payer	≠ freight payer	Freight payer not in control of transport planning
Entity in charge of origin site		≠ freight payer	≠ freight payer	
Availability of transport alternatives at short notice		yes	yes	Little willingness on suppliers' side to change situation
Latest possible time for placing transport order		≤ 1 day prior to shipping	≤ 1 day prior to shipping	
Transport vehicle ownership		ad-hoc leasing	ad-hoc leasing	
Non-transport related measures for addressing demand deviations		none	none	

However, the elaboration of transport plans and the release of transport orders are not in the responsibility of the freight payer, but of the numerous (partly small) suppliers of steel scrap. The freight payer only negotiates freight rates and pays generated rail transports. As a result, transport plans and forecasts can only provide suppliers of steel scrap, with which the freight railway has no contractual relationships. Freight payers, having a direct contractual relationship with suppliers of steel scrap, do actually seek a more intense collaboration and coordination with their suppliers. However previous efforts have largely failed, as steel scrap suppliers demand financial compensations for implementing collaborative approaches.

From the suppliers’ point of view, there is little willingness to change current situation on their own and the negotiation position of steel mills is not strong enough to enforce a change (chapter 8.4.2.3). Steel mills grant suppliers of steel scrap flexible delivery due dates for agreed quantities. This is associated with high transport flexibility, as steel scrap transports are shipped in single wagonloads. Although rail is – due to its high specific weight – clearly the preferred transport mode for steel scrap shipments, steel scrap

processors and traders have nonetheless the possibility to engage road-based transport service providers at short-notice.

### 8.4.3.3 Conclusion

Accurate transport forecasts as well as balanced daily shipments are expected to be possible in the steel scrap sector (Table 8-24). The activation of this potential requires though a transfer of transport planning competences from individual suppliers of steel scrap to one single actor of the supply chain network. Evident candidates for that are steel mills, which already act as freight payers. Freight railways itself only have limited possibilities to enforce this development, as they maintain contractual relationships with steel mills but not with suppliers of steel scrap.

**Table 8-24: Forecast potential for rail transports in the steel scrap sector**

Feature		Value			
Forecast potential	Accuracy	low	medium	high	
	Share of total shipments <sup>1</sup>	minority		large majority	
	Frequency	event-driven	monthly	weekly	daily
	Time horizon	≤ 1 week	2 - 3 weeks		≥ 1 month
	Level of detail	week	day		hour

<sup>1</sup> based on total transport volumes in transport sector

## 8.5 Summary

### *Mineral Oil Sector*

- The basic process of transport planning is comparable between analysed shippers in this sector. However, both planning quality and time horizon strongly differ. This is the consequence of highly individual planning preconditions and instruments to cope with demand variations.
- A majority of shippers is expected to be able to forecast its shipments with a medium accuracy (80-90%) covering a time period of 2-3 weeks at maximum.
- A minority of shippers are able to forecast its shipments with a high accuracy of more than 90% over a time period of 2-3 weeks or more.

### *Gravel Sector*

- Transport planning behaviour and their influencing factors are highly similar for all analysed shippers in this sector.
- There is no apparent forecast potential in the gravel transport sector, exceeding a weekly time horizon. Even this period is subject to major uncertainty.
- Involved actors in the rail-based logistic chain of gravel transports – freight railway, shipper (producer) and buyer of gravel – are not in the position to change existing market forces, which are largely driven by the construction industry.

### *Steel Scrap Sector*



- Transport planning behaviour and their influencing factors are highly similar for both analysed freight payers.
- Accurate transport forecasts as well as balanced daily shipments are expected to be possible.
- However, today's contractual relationships and market forces will make it difficult to enforce a change of current situation in this sector.

#### *General observations*

A general willingness to cooperate was experienced during interviews with shippers in Switzerland, notably regarding the submission of additional (non-binding) information. Following reasons may explain this situation:

- Contractual relationships between shippers and freight railway are often historically grown and long-term orientated. This is also because rail based alternatives are still quite limited in Switzerland, notably for shippers with large transport volumes. A good understanding between shipper and its freight railway is therefore in the interest of both.
- Nonetheless, shippers are strongly interested in a competitive environment for rail freight shipments. Having potential alternatives is a powerful argument during price negotiations. Shippers would abet a monopolistic situation if they pushed its freight railway with uncooperative actions to withdraw from certain transport sectors.
- The cultural influence should not be underestimated. In Switzerland, there is a distinct culture of dialogue and compromise, which becomes evident not least in the political system. This positive attitude was particularly apparent at transport planners working in the mineral oil sector on both shipper and freight railway side. It notably manifested in a mutual willingness to find acceptable solutions for both sides in case of short-term modifications of ordered trains. Collaborative approaches are therefore often viewed favourably.

# 9 Potential of Collaborative Approaches

---

## 9.1 Synthesis of Present Findings

Chapter 6 identified and discussed a number of collaborative approaches, based on the empirical analyses of operational rail freight processes. Chapter 8 empirically analysed three different transport sectors and discussed – among others – the ability of shippers to provide necessary information about future shipments. Figure 9-1 synthesises the findings from these two chapters and reveals the actual potential of identified collaborative approaches.

Overall, shippers from the gravel sector are little suited for collaborative approaches on the operational level. They hardly know more than the freight railway about future shipments and are not in the position to change current situation without risking to lose market shares.

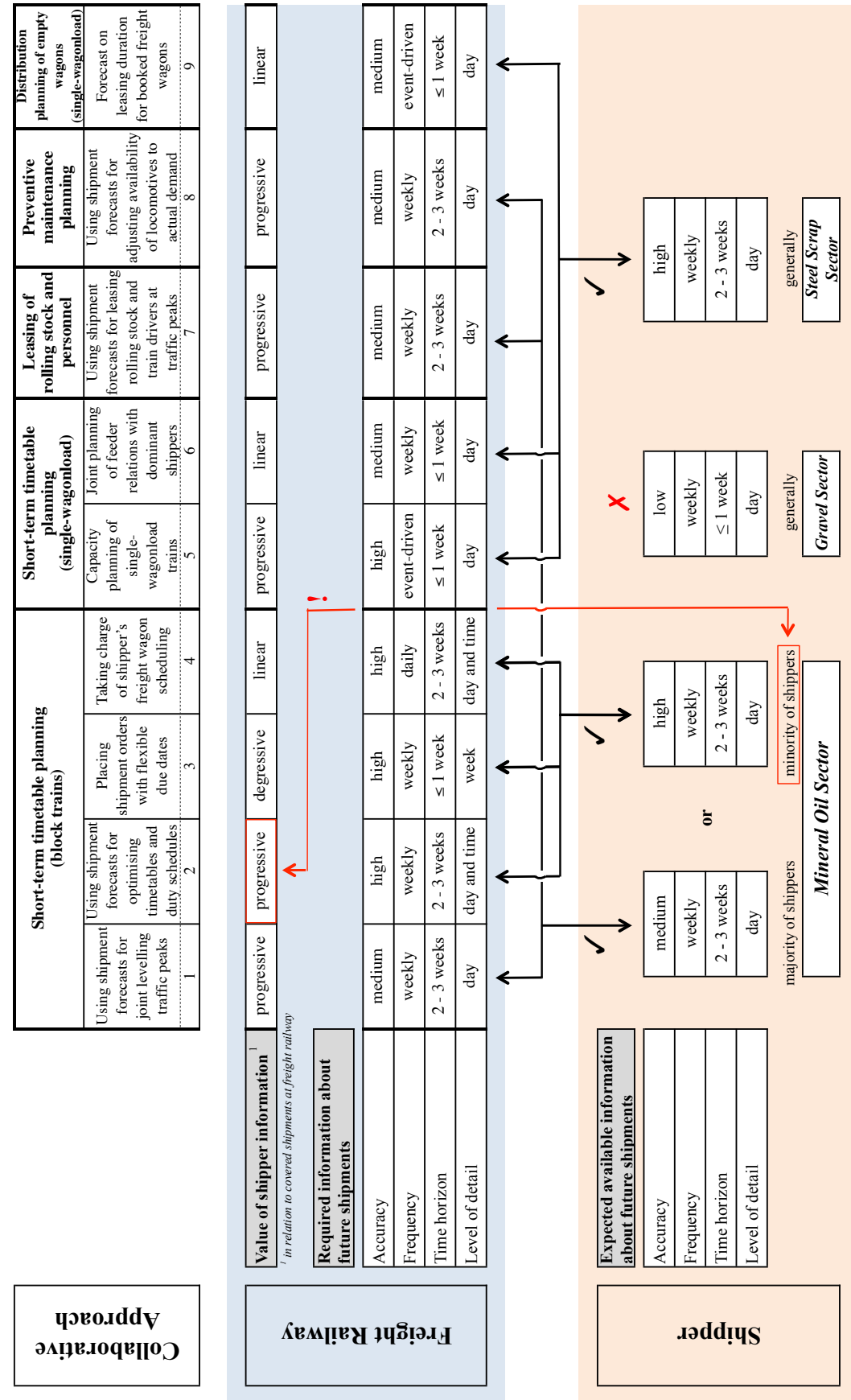
The situation is more promising for shippers from the mineral oil sector. The majority of shippers is expected to qualify for collaborative approaches 1, 7, and 8 (Figure 9-1). For all three collaborative approaches, the value of provided information increases progressively with the percentage of covered shipments at freight railway. Due to the significance of the mineral oil sector in the overall transport performance (Table 2-1), a substantial benefit is already given. Nonetheless, the integration of other sectors would increase the benefit of those collaborative approaches over proportionally.

A minority of shippers from the mineral oil sector further qualify for collaborative approaches 2, 3, and 4. However, as long as provided information cover a small part of shipments only, the overall benefit of collaborative approach 2 remains low. This is because the value of provided information increases progressively with the percentage of covered shipments at freight railway. A successful implementation of this collaborative approach would thus require the analogue integration of shippers from other transport sectors.

The steel scrap sector qualifies for collaborative approaches 5, 6, and 9. Due to the progressive value increase of provided shipper information for collaborative approach 5, a significant benefit will only occur if shippers from other sectors are integrated analogously.

Figure 9-2 summarises these conclusions graphically.

Figure 9-1: Suitability of collaborative approaches at analysed sectors



**Figure 9-2: Summary of results**

No	Collaborative Approach	(1)	(2)		
			A	B	C
6	Joint planning of feeder relations with dominant shippers	Green	Not applicable	Not applicable	Green
1	Using shipment forecasts for joint levelling traffic peaks	Green	Green	Red	Not applicable
7	Using shipment forecasts for leasing rolling stock and train drivers at traffic peaks	Green	Green	Red	Not applicable
2	Using shipment forecasts for optimising timetables and duty schedules	Green	Yellow	Red	Not applicable
9	Forecast on leasing duration for booked freight wagons	Yellow	Not applicable	Not applicable	Green
5	Capacity planning of single-wagonload trains	Yellow	Not applicable	Not applicable	Green
8	Using shipment forecasts for adjusting availability of locomotives to actual demand	Yellow	Green	Red	Not applicable
3	Placing shipment orders with flexible due dates	Yellow	Yellow	Red	Not applicable
4	Taking charge of shipper's freight wagon scheduling	Yellow	Yellow	Red	Not applicable
10	Publishing unused shipment time slots for block trains	Red			
11	Forecast on releasing time of booked freight wagons	Red			
12	Early delivery of empty wagon bookings	Red			

(1) Value of collaborative approach for freight railway (chapter 6)

- expected productivity gain disproportionately high to risks & costs
- expected productivity gain proportionately to risks & costs
- expected productivity gain disproportionately low to risks & costs

(2) Qualification of analysed sectors for collaborative approaches (chapter 8)

- qualify for collaborative approach
  - partly qualify for collaborative approach
  - not qualified for collaborative approach
- A = Mineral Oil Sector; B = Gravel Sector; C = Steel Scrap Sector  not applicable

A successful implementation needs the knowledge about the future process design, possible incentives for ensuring the collaboration of participants, and the approximate quantitative benefit. In the following chapters 9.2 - 9.4, these aspects are exemplarily discussed for the three most promising collaborative approaches 1, 6, and 7 (Figure 9-2)<sup>71</sup>.

KORELL AND SCHASCHKE (2007) provided valuable generic guidelines and theoretical backgrounds for the integration of customers in company procedures. Yet, the specific approach for dealing with freight rail related aspects had to be developed by the author of this study. Being aware of the complexity of implementing new collaborative approaches, the analyses focus on the most relevant aspects rather than creating detailed implementation concepts.

<sup>71</sup> The case study for collaborative approach 7 will focus on the leasing of locomotives and can analogously be adopted for train drivers and freight wagons.

## 9.2 Approach 1 – Using Shipment Forecasts for Joint Levelling Traffic Peaks

### 9.2.1 Motivation for Participants

The motivation for freight railways has already been discussed in chapter 6.2.3.1: The expected productivity gain is disproportionately high compared to possible risks and costs, giving freight railways a high motivation to implement this collaborative approach.

The motivation for shippers to participate in this collaborative approach is less obvious. For the joint levelling of traffic peaks, the cooperation of shippers is required twice: (A) to provide shipment forecasts and (B) to postpone certain shipments in case of exceptional traffic peaks.

(A) In the course of conducted expert interviews, it became evident that providing available shipment forecasts is not a critical issue per se, as long as they are not associated with any obligations<sup>72</sup>. Further, analyses in the mineral oil sector have shown that there is generally a monthly transport plan, which is constantly updated during month. Shipment forecasts are thus simply extractable from the current state of planning. The railway should track forecast accuracies for each shipper in the beginning. This has various advantages: First, the railway attains certainty about the trustworthiness of submitted forecasts. Second, the railway could act as neutral intermediary to exchange “best-practices” between competitors. This will increase the motivation of underperforming shippers to improve their forecast qualities. Financial incentives for getting forecasts by shippers are not expected to be necessary.

(B) The willingness of shippers to postpone certain shipments at traffic peaks is more questionable. First, shipments respond to actual demands. The empirical analyses in chapter 8 have shown that postponements are largely unrealistic in the gravel sector while the situation in the mineral oil sector is more promising for a number of reasons. Second, it can be assumed that transport plans represent the respective optima under given transport conditions from the shippers’ perspective. Each externally induced change request is therefore for the worse. However, this consideration has to be qualified for highly dynamic transport sectors. Such sectors are frequently forced to change transport plans at short-term notice. In this case there is no “optimal” transport plan, which has been elaborated with great effort. Such transport plans are in the first place a product of external constraints. Change requests from railways would thus just be one of several external influences. Nonetheless, any changes in transport plans are associated with an increased effort on shippers’ side and potentially impaired turnaround times of train compositions. This will have to be compensated by the freight railways. A promising approach would be to grant a discount for shippers accepting a requested shipment

<sup>72</sup> This statement refers to the analysed sectors in this study but is assumed to be valid for other transport sectors within Switzerland as well. For details please refer to chapter 8.5.

postponement. This focused incentive system makes sure that the general pricing level remains untouched and discounts are only given as a result from a direct benefit at the freight railway.

## 9.2.2 Process Design

The approach is illustrated using the example of block train services in the mineral oil sector. First, today's scattered and voluntary forecasts of mineral oil transports should be replaced by standardised and compulsory forecasts with a time horizon of two weeks (Figure 9-3)<sup>73</sup>. These forecasts are then aggregated by the freight railway, which reveals exceptional traffic peaks. These traffic peaks will be jointly levelled in close cooperation with selected shippers.

**Figure 9-3: Design of new process - overview**

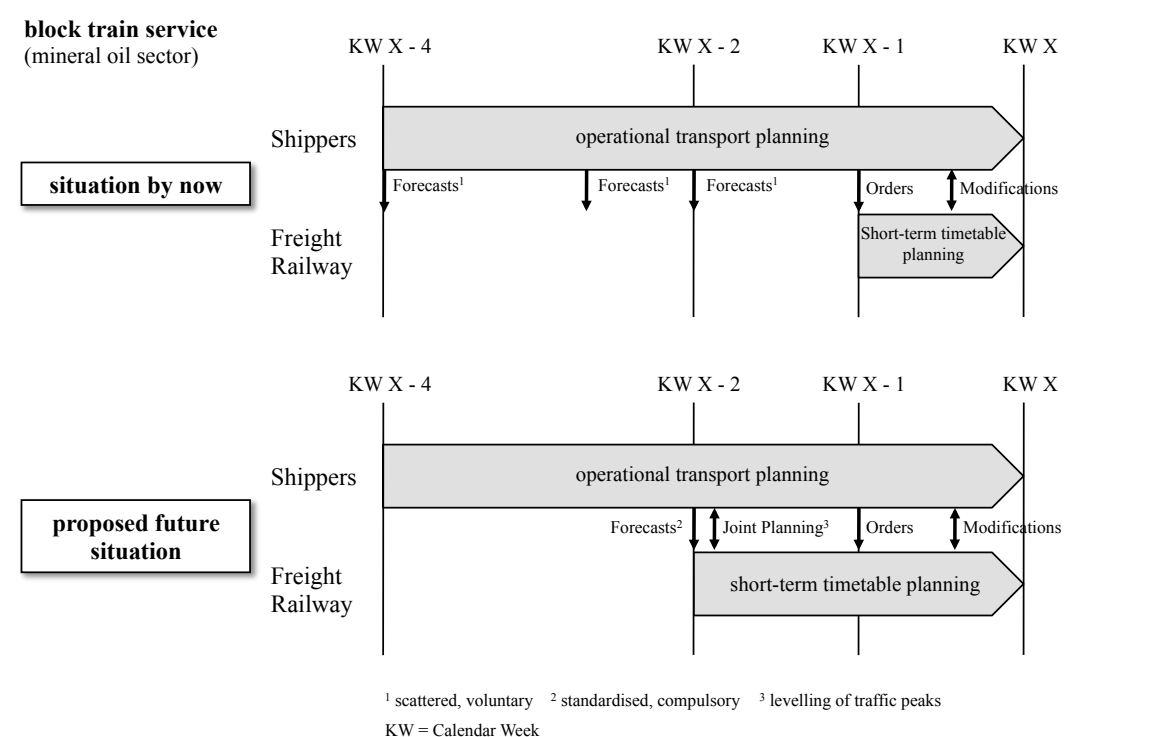


Figure 9-4 shows the proposed process in more detail. Overall, organisational changes remain little and will not increase staff size or require new or adapted IT-equipment. As today, shippers send their shipment orders midweeks for the upcoming week. New is the concurrent compulsory submission of shipment forecasts for the week after next, having following characteristics:

- **Commitment:** Shippers elaborate non-binding shipment forecasts at best of their knowledge and belief. Reactions from interviewed shippers have shown that the willingness to provide forecasts on a non-binding basis is largely given, while a

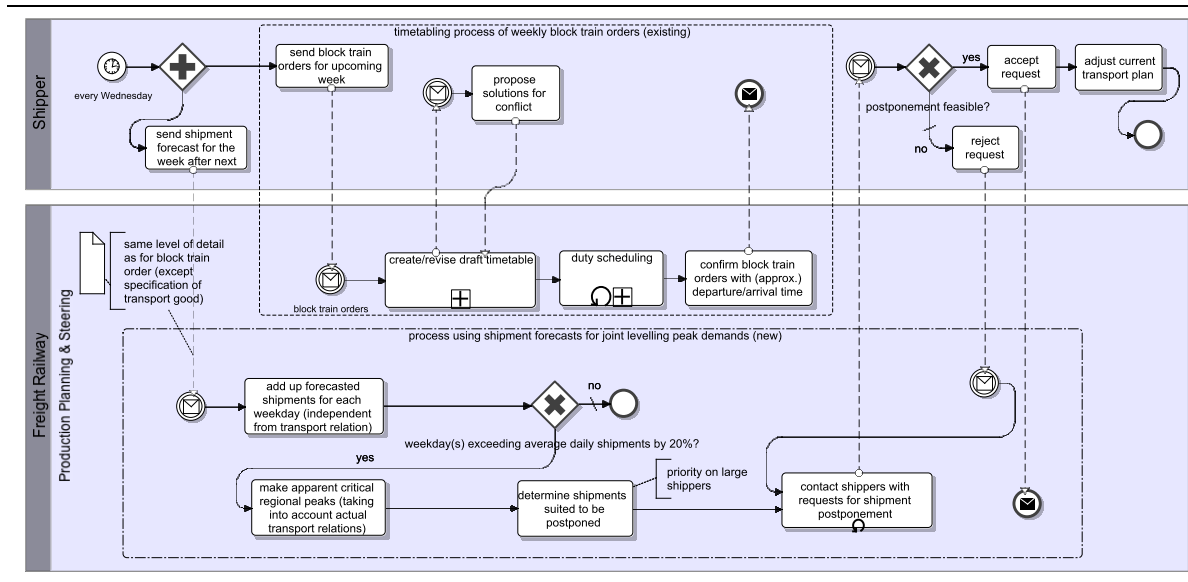
<sup>73</sup> Shipments at public holidays and the announcement of plant vacations/revisions are excepted from this standard procedure. This information is usually known several weeks to months in advance.

binding character would meet great opposition. Non-binding forecasts are tolerable in this case, as they are used to identify exceptional traffic peaks only. On this aggregation level, forecast errors will partly compensate each other, due to the large number of forecasted shipments.

- **Level of detail:** The level of detail corresponds with the one for shipment orders: Shipment day, transport origin/destination, and approximate times of departure/arrival are indispensable forecast information.
- **Format:** For efficiency reasons, submitted forecasts must have a uniform format, enabling a largely automatized aggregation. Ideally, the same format is used for shipment orders and forecasts.

In a next step, planners at the freight railway aggregate submitted forecasts, yet on a relation-independent level. This first aggregation shows the approximate distribution of transport volumes over the week. Respecting the fact that a certain degree of variations in daily transport demand are inevitable, the focus for a pro-active levelling should be on traffic peaks exceeding a pre-determined percentage from average (e.g. 20%). For identified traffic peaks, more detailed analyses on the level of transport relations and origins/destinations are necessary. This provides important information about critical regional peaks. Planners at the freight railway will then have to decide by experience, which shipments are suited to be postponed on a voluntary basis. The highest chance of success is expected to be with large shippers. They generally operate several train compositions and numerous distribution depots, giving them more flexibility to adjust their transport plan. Large shippers are thus preferably contacted first.

**Figure 9-4: Design of new process - details**



## 9.2.3 Quantification of Benefit

### 9.2.3.1 Up-front Analyses

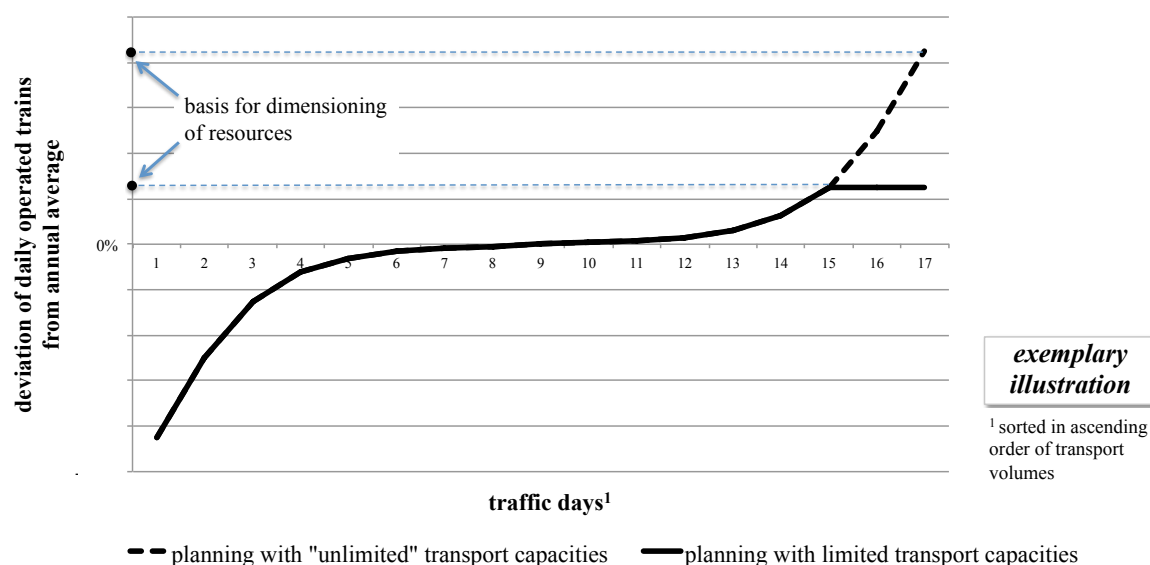
Two factors decisively influence the benefit and suitability of joint levelling peak demands: The applied planning principle and the weekly/daily variations of transport demand. These aspects are analysed first.

#### 9.2.3.1.1 Applied Planning Principle

A fundamental decision of a freight railway is to decide, whether it wants to encounter transport demand with “limited” or “unlimited” transport capacities. The effect of these two planning principles on the dimensioning of resources (locomotives, freight wagons, personnel) is exemplarily depicted in Figure 9-5.

If a freight railway is willing to cover any transport demand<sup>74</sup>, an “unlimited” transport capacity is necessary. As a result, exceptional but rare traffic peaks must be taken as planning reference for the dimensioning of resources. If transport capacities are hardly adjustable, over-capacities are inevitable for the vast majority of traffic days. In this case, the levelling of few traffic peaks already leads to a significant efficiency gain.

**Figure 9-5: Effect of applied planning principles on dimensioning of resources**



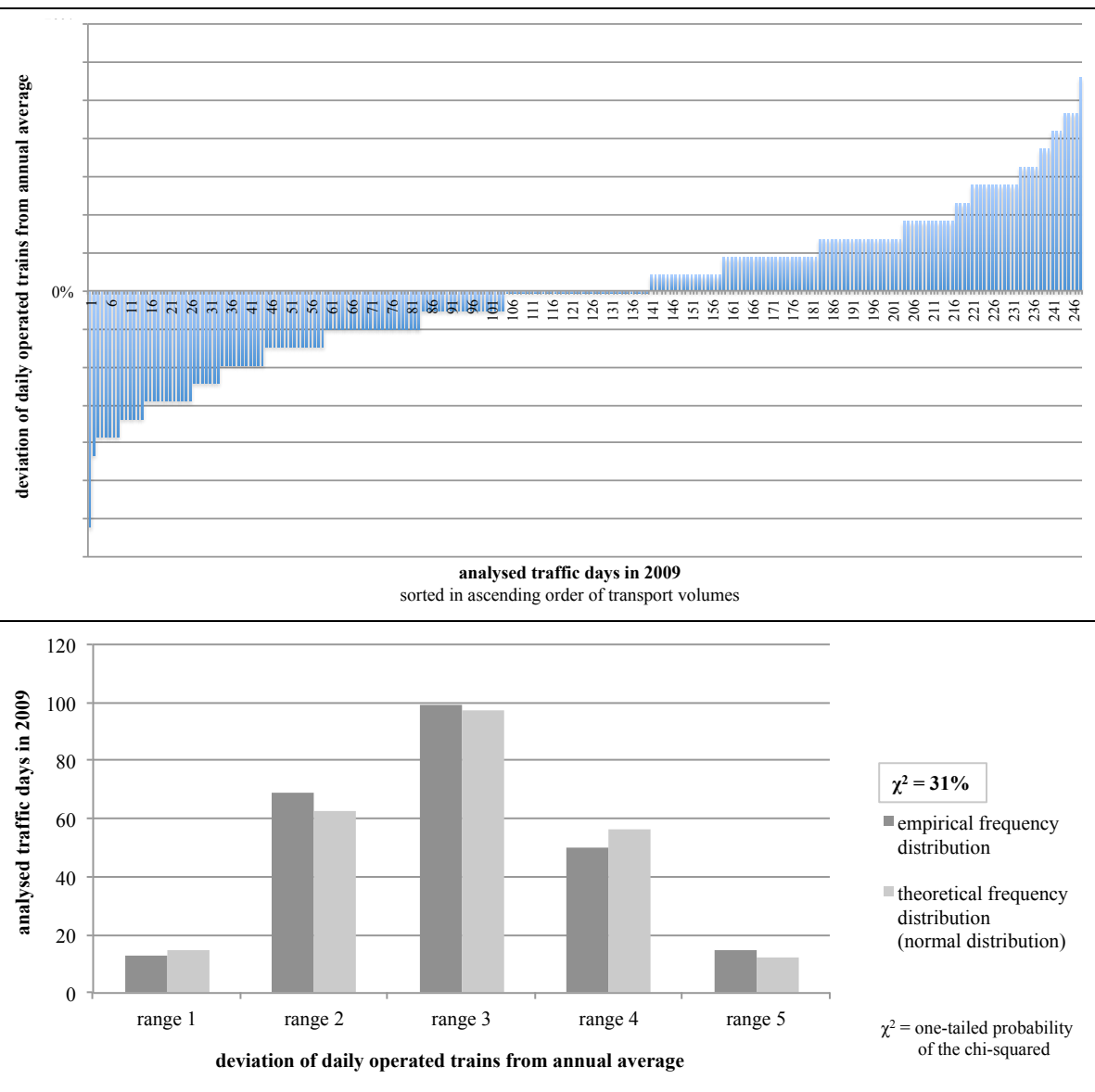
The situation becomes different, if the freight railway plans with limited transport capacities. In this case, incoming transport requests are rejected after reaching a certain maximum limit. This automatically caps traffic peaks. Further levelling measures would thus generate little productivity gains only.

<sup>74</sup> For existing customers and within the freight railway’s geographical area of operation.



Provided data about mineral oil rail transports show the applied planning principle of SBB Cargo in 2009. Weekends, public holidays<sup>75</sup> and the week between Christmas and New Year have been filtered out, as they would falsify the analysis. The result is shown in Figure 9-6 (the precise figures cannot be disclosed for reasons of confidentiality). A maximum limit of operable trains is not observable, which implies that the freight railway follows the planning principle of “unlimited” transport capacities. Further, the statistical test for a normal distribution ( $\chi^2$ ) yielded a positive result, stating a significance level of 10%. This mathematical indicator proves a lack of capped transport volumes, which would go along with limited transport capacities.

**Figure 9-6: Deviation of daily operated trains from annual average**



<sup>75</sup> New Year’s Day, Good Friday, Easter Monday, Labour Day, Ascension Day, Pentecost, Christmas Day

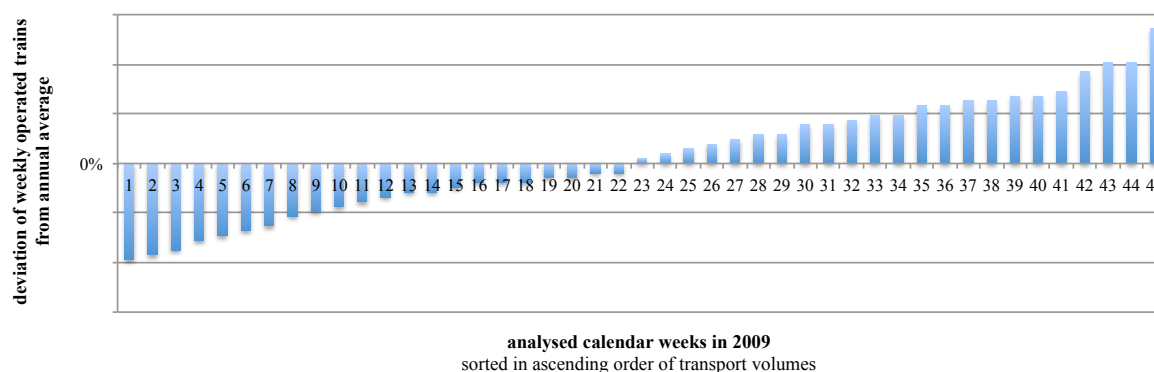
### 9.2.3.1.2 Weekly Deviations of Transport Demand

Lean inventory philosophies make the postponement of shipments from one week to another virtually impossible for shippers. Weekly deviations of operated trains can therefore be regarded as the minimal percentage, which transport capacities must be dimensioned on. A further reduction is only possible with enforcing measures, such as the rejection of transport requests.

This has a direct consequence for the approach of joint levelling peak demands. The potential for productivity gain is only given if daily traffic peaks significantly exceed weekly traffic peaks.

Empirical analyses with the same data as in chapter 9.2.3.1.1 show that this condition is given for the mineral sector of SBB Cargo (Figure 9-7; the precise figures cannot be disclosed for reasons of confidentiality). Calendar weeks with public holidays have been filtered out to ensure the comparability of data.

**Figure 9-7: Deviation of weekly operated trains from annual average**



These two up-front analyses confirm the principal suitability for applying the collaborative approach of joint levelling traffic peaks in the sector of mineral oil transports.

### 9.2.3.2 Calculation of productivity gain

In order to estimate the productivity gain of joint levelling peak demands, the following rules were set up for the postponement of shipments<sup>76</sup>:

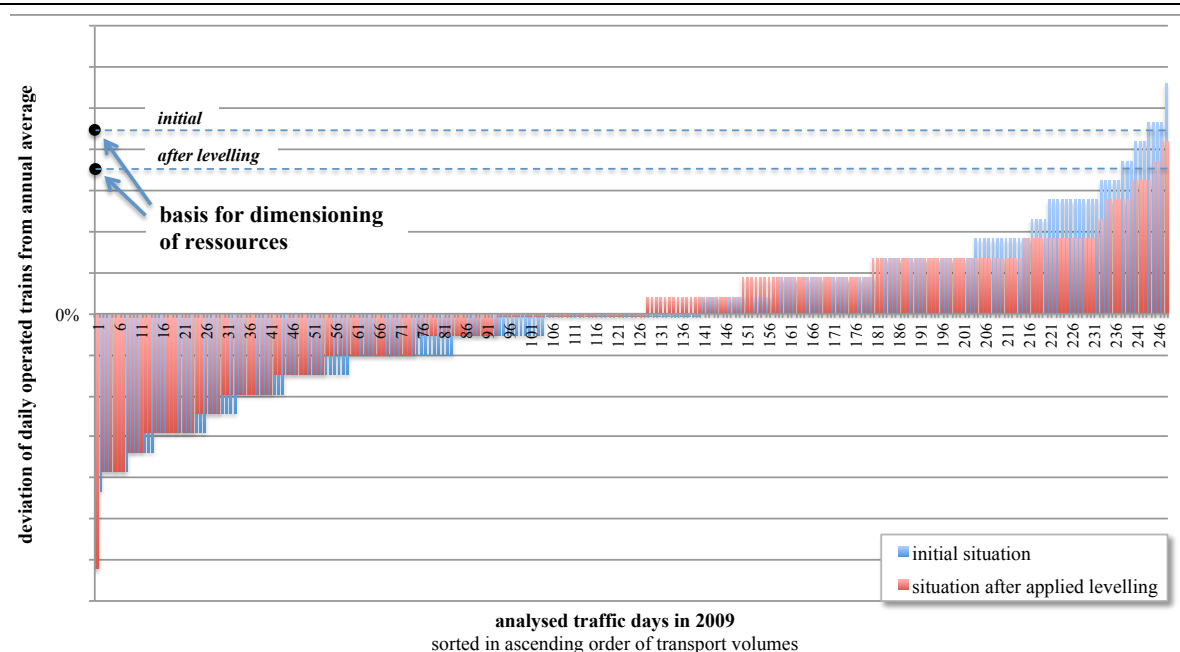
1. Traffic days are attempted to level, if their expected number of shipments exceed the annual average by 20% or more.
2. 90% of planned block trains from shippers are not flexible in terms of time.
3. Remaining shipments are postponed according to following procedure:
  - Pull forward shipments on the day before, provided that shipments on this day do not exceed the annual average. Else:

<sup>76</sup> The indicated quantitative figures are best estimates from the author of this study and thus have to be viewed with caution. The same consequently applies for the derived quantitative results.

- Postpone shipments on the day after, provided that shipments on this day do not exceed the annual average. Else:
- Pull forward shipments on the day before yesterday, provided that shipments on this day do not exceed the annual average<sup>77</sup>. Else:
- Postpone shipments on the day after tomorrow, provided that shipments on this day do not exceed the annual average. Else:
- Shipments cannot be postponed.

These rules have been applied on the mineral oil rail transports of SBB Cargo in 2009. Although not all traffic peaks could be levelled respecting the above rules, a significant levelling is nevertheless noticeable (Figure 9-8).

**Figure 9-8: Effect of applied levelling measure**



The applied joint levelling clearly lowers the dimensioning level. The precise figure cannot be disclosed for reasons of confidentiality but is within the range of 5% - 15%.

Transport capacities of locomotives are nearly stable at short-notice. As a logical consequence, reducing the dimensioning basis will lower the number of needed locomotives for mineral oil transports by nearly the same percentage as well in a long-term perspective. Although mineral oil transports have specifically dedicated locomotives for planning, internal planning interactions are common with other transports sectors to optimise their utilisation rates. It is not possible to precisely quantify this effect with available data. It is assumed that around 50% of the calculated saving effect is already realized through these internal planning interactions with other transport sectors. Even

<sup>77</sup> In reality, shipments are rather pulled forward the day before. Concurrently, the same number of planned shipments is pulled forward from the day before to the day before yesterday.

with this assumption, the collaborative approach still contributes to a significant efficiency gain of locomotives used for mineral oil transports.

Transport capacities of train drivers are a lot more flexible than locomotive capacities (chapter 6.6.1). The efficiency gain from a joint levelling of traffic peak will therefore be significantly lower and thus most probably negligible.

## **9.3 Approach 2 – Joint Planning of Feeder Relations with Dominant Shippers**

### **9.3.1 Motivation for Participants**

The motivation for a freight railway is generally given as it improves the effectiveness of single wagonload services through increased train utilisation rates (chapter 6.3.3.2). In order to transform this effectiveness gain in financial benefit, freed up locomotives and train drivers must be used for other transports. The freight railway will therefore primarily be motivated to apply this approach on traffic days, where a general shortage of transport capacities is most likely to occur. The proposed approach is also associated with a cultural change for planners. The single wagonload network will become more flexible at short-notice and decisions about cancellations of trains have to be made on the basis of qualified estimations from shippers. Planning thus becomes more uncertain and challenging, which may cause opposition. Sharing experiences with planners of block train services could help prevent this potential scepticism. Temporary job rotations between planners of block train and single wagonload services could be a helpful measure as well.

The cooperativeness on shipper side will not be given without financial incentives. Today's situation for shippers using single wagonload services is characterised by a high transport planning flexibility, which manifests – at least in the analysed steel sector of Switzerland – in a lack of operational transport plans covering more than a couple of days. Without a financial incentive, there is no reason for shippers to restrict this flexibility. Further, the cooperation is also associated with an extra planning effort.

A financial incentive system is consequently proposed for each proactively avoided train cycle on a certain feeder relation. Incentive levels should depend on weekdays and time of operation, expressing the different benefits for the freight railway. For example, a bonus is only granted if shippers make train cycle dispensable on Wednesday or Thursday, typically being the busiest days of the week. The granted bonus should base on the monetised efficiency gain of train drivers and locomotives, which are freed up to operate other trains.

For this collaborative approach, there is an increased risk of creating undesired incentives. Two effects are particularly conceivable:

The first undesirable effect may occur when shippers indicate too optimistic estimations about expected transport quantities for the upcoming year. On this basis, the freight railway would dimension transport capacities too generously in its single wagonload network. This would allow shippers cancelling feeder trains more frequently than justified during the year. This risk is very limited in practice. Due to the large experience about typical transport volumes on the freight railway side, artificial increases of expected annual transport volumes from shippers will be quickly detected.

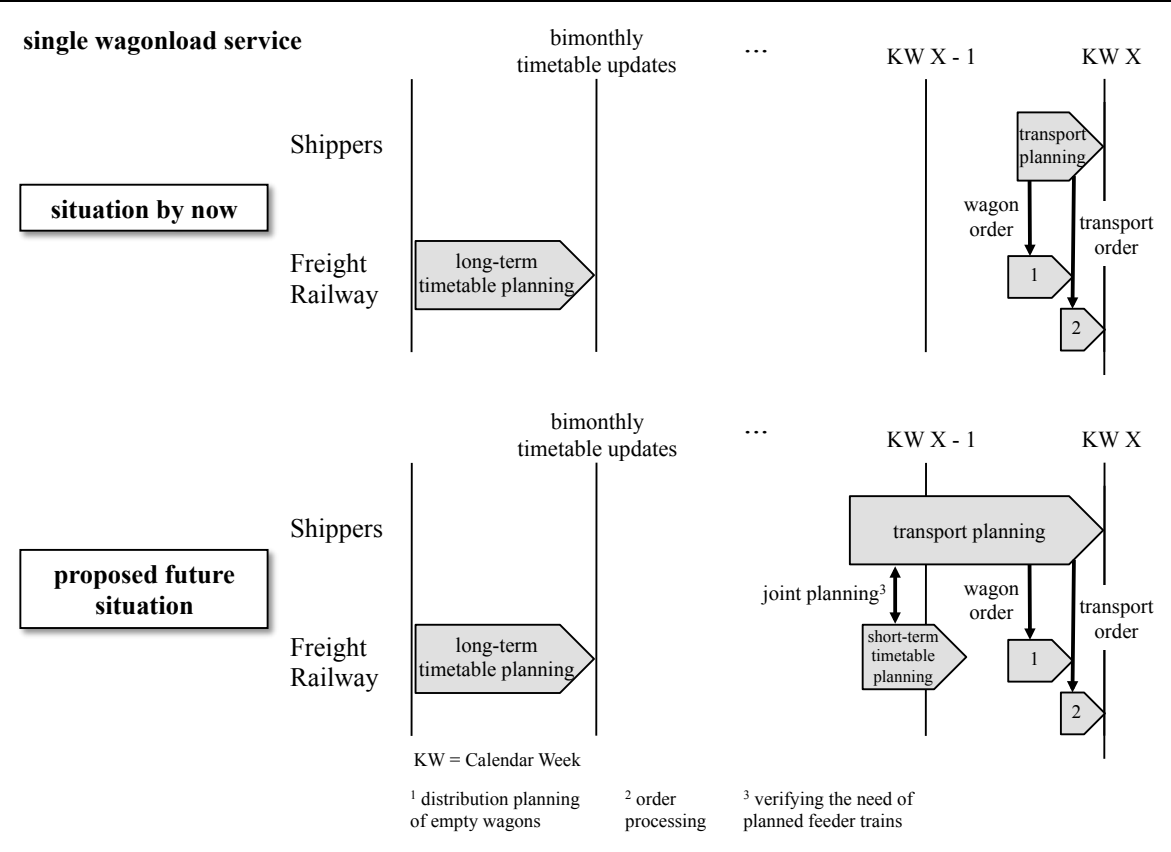
The second undesirable effect requires a careful control: Shippers could be motivated to cancel trains and ship goods on road instead. The consequences are unimproved train utilisation rates and – even more important – a loss of turnover, which is even rewarded by a bonus overall. Due to these severe consequences, effective preventive measures are compelling. An unwanted shift from rail to road can be detected by controlling shipped transport volumes or utilisation rates of feeder trains, which are mainly used by the respective shipper. The expressiveness of the first indicator is limited due to its strong dependences on economic trends. The second indicator is more suited to detect potential mode shifts – especially while applying the proposed approach of joint planning feeder relations. The cancellation of trains should result in increased utilisation rates of remaining trains on the concerned feeder relation. It is therefore recommended to withhold bonus payments, until an end-of-year calculation of affected feeder trains have shown an improved overall train utilisation rate.

### **9.3.2 Process Design**

This collaborative approach leads to a new process in the planning of single wagonload service, closing the gap between bimonthly timetable updates and short-term transport orders (Figure 9-9). This new joint planning process between shippers and carriers verifies the actual need of planned feeder trains in the single wagonload network. Planning horizon and timing of this process are preferably aligned with short-term timetabling of block trains (chapter 6.2.1). This enables a seamless mutual use of released resources.

However, this process is only applicable for feeder relations with several daily trains. This is because single wagonload traffic is based on a network, which connects existing service points on a regular, largely demand-independent basis. This allows shippers flexibly placing shipment orders at very short-notice. To keep this significant advantage, a minimal demand-independent offer must be granted for all feeder relations. Further, this process works best with shippers dominating certain feeder relations. Although single wagonload trains may comprise goods from many different customers, needed transport capacities are often determined by few large shippers only. In this case, shipping volumes from small shippers do not necessarily have to be integrated in this process.

**Figure 9-9: Design of new process - overview**



**Figure 9-10: Design of new process - details**

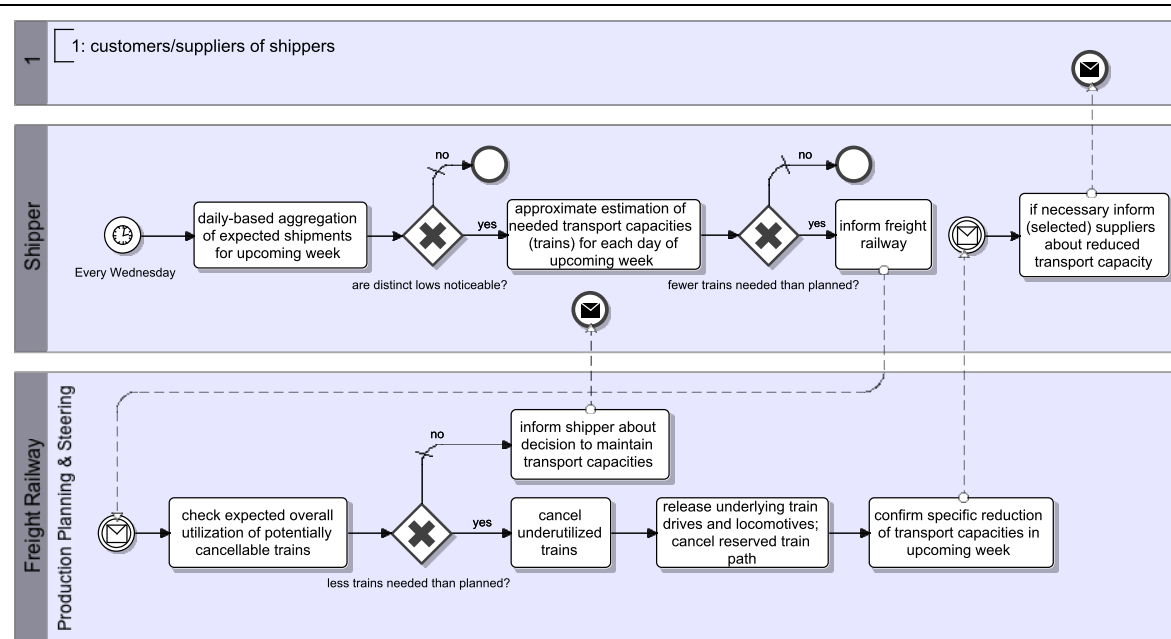


Figure 9-10 shows the proposed operational process in detail<sup>78</sup>. Shippers aggregate their expected shipments for the upcoming week every Wednesday. The objective is to identify days with distinct lows of shipments, rather than exact numbers. If distinct lows are noticeable, needed transport capacities are estimated for these days and compared with currently planned ones. Shippers inform the freight railway if needed transport capacities diverge from planned ones in the scale of one entire train in both directions of the feeder relation<sup>79</sup>. To reach this amount, an active shift of certain shipments may sometimes be necessary. In a next step, the freight railway checks the expected overall utilisation of potentially cancellable trains, e.g. by taking into account provided information from other shippers on this feeder relation. If fewer trains are needed than planned, one or several train pairs are cancelled and associated train drivers, locomotives and train paths are freed up for other transports. The specific reduction of transport capacities is confirmed to affected shippers. They might have to inform their rail-based customers/suppliers about reduced transport capacities as well and possibly declare a refuse of freight acceptance for this very day.

The additional effort at both freight railways and shippers remains little overall and will expectedly neither increase staff size nor require new or adapted IT-equipment. This is because no detailed planning and forecasts are necessary and the process only starts in case of exceptional lows at selected feeder relations.

The above-described process does not change today's initial planning of feeder trains. The number of trains is dimensioned to fulfil expected transport demand, including eventual peaks. The proposed collaborative approach subsequently cancels some of these planned trains, if they turn out to be underutilised. A contrary planning strategy is conceivable too: The freight railway dimensions the number of feeder trains on basic transport demand only. Peak demands are thus intentionally not covered during annual/bimonthly planning. In this case, dominant shippers are required to order additional feeder trains on a weekly basis, if their expected transport demand exceeds available transport capacities. The decision for the appropriate planning strategy depends on the individual situation at feeder relations. The first planning strategy is preferably applied on a feeder relation with a demand characteristic showing distinct lows rather than peaks, while the second planning strategy better suits in the reverse case.

### 9.3.3 Quantification of Benefit

Two feeder relations in the Swiss single wagonload network of SBB Cargo were chosen to quantify the possible benefit of this approach. Both relations are dominated by steel mills, which obtain steel scrap largely on rail and deliver their steel products in reverse

<sup>78</sup> It presupposes the prior identification of suitable feeder relations and trains and a cooperation agreement with qualified shippers.

<sup>79</sup> Cancelling trains in one direction would mostly create inefficient empty runs only.

direction. Several daily trains are regularly operated on each direction. The selected feeder relations cover a distance of about 70 to 80 kilometres each.

Provided data from SBB Cargo cover the first semester 2010 and indicate the actual and maximum possible weight/length of operated trains on the respective feeder relation. Based on these figures, the utilisation rate for each operated train has been measured in weight and length, of which the higher one has been used for further calculations. The number of daily trains is regarded as reducible if the average train utilisation rate of trains and direction is less than 50% (in case of two scheduled trains), 66% (in case of three scheduled trains), or 75% (in case of four scheduled trains) for a specific day.

Analysed traffic days have been grouped into three categories:

- 1) number of daily trains reducible in both directions of feeder relation.
- 2) number of daily trains reducible in one direction of feeder relation.
- 3) number of daily trains not reducible.

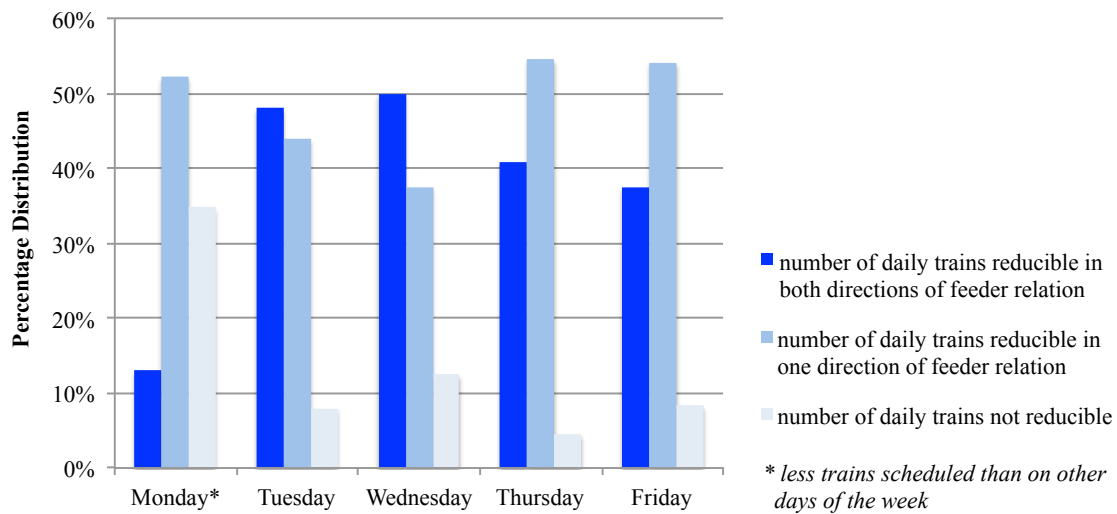
Within these three categories, analysed traffic days were sorted in ascending order according to the average utilisation rates of trains heading to the marshalling yard.

The results for feeder relation A show that the potential for further improvements is very low. At 83% of all analysed traffic days, no trains are reducible without creating a shortage of transport capacities. At 14%, the number of trains could be reduced in one direction only. Cancelling such trains makes little sense from a productivity perspective, as they are generally part of a train cycle starting and ending at the marshalling yard. Only in 3% of analysed traffic days the number of scheduled trains could be reduced in both directions. This percentage is clearly too low for taking any measures.

The results for the second feeder relation B are more promising. At nearly 40% of analysed traffic days the number of scheduled trains could be reduced in both directions. This is a significant potential for the proposed approach of joint planning feeder relations.

Despite of this significant potential, no joint planning is necessary, if these days are strongly concentrated to few or even one weekday. In this case, the freight railway can simply reduce the number of regularly scheduled trains during annual/bimonthly planning. Further, the actual benefit of reducing trains would be rather low on days with typical low transport demands. To check these issues, data from feeder relation B have been aggregated on weekdays (Figure 9-11).



**Figure 9-11: Distribution of reducible trains on feeder relation B over the week**

The results in Figure 9-11 are meaningful in several respects:

- Days with a reducible number of trains in both directions are quite equally distributed from Tuesday to Friday<sup>80</sup>. A distinct concentration is not noticeable.
- A general reduction of trains – as done on Monday – is not possible for the other days of the week without creating a shortage of transport capacities.
- Average transport demand requires rail transport capacities of x.5 trains. In this situation, a static planning approach with annual/bimonthly planning cycles reaches its limits.
- A joint planning of feeder relations could reduce the number of daily trains in both direction of the feeder relation at nearly every second Tuesday, Wednesday, and Thursday. Train savings on these weekdays are particularly interesting for the freight railway as they correlate with generally high traffic demands in other sectors such as mineral oil.

Despite of these promising results in the specific case of feeder relation B, the overall potential of this collaborative approach is limited for improving overall productivity at the freight railway. This is due to a number of required conditions, which limit an extensive implementation (Table 9-1). The overall applicability of joint planning feeder relations is calculated through a multiplication of estimated individual probabilities.

<sup>80</sup> Fewer trains are regularly scheduled on Monday than on the other days of the week, considering a general lower transport demand.

**Table 9-1: Conditions for joint planning feeder relations**

Condition	Probability <sup>1</sup>	
	optimistic scenario	pessimistic scenario
Feeder relation with several daily trains	75%	50%
Shipper largely dominating feeder relation	75%	50%
Average transport demand requires rail transport capacities of x.5 trains	75%	50%
Trains are reducible in both directions of feeder relation	75%	50%
Reducible train pairs are on weekdays with generally high demand (Tue-Thu)	80%	60%
Freed up resources from saved train pairs can be used for other transports	40%	20%
<b>Suited feeder relations for joint planning</b>	<b>10%</b>	<b>1%</b>

1) estimate from author

The applicability rate of joint planning feeder relations is expected to be in the range of 1% to 10% only. Hence, the implementation of this collaborative approach can improve the effectiveness on certain feeder relations of the single wagonload network, but its effect on overall productivity will remain rather little.

## 9.4 Approach 3 – Using Shipment Forecasts for Leasing Locomotives at Traffic Peaks

### 9.4.1 Motivation for Participants

Three different actors have to agree for this collaborative approach: Shippers as provider of forecasts, passenger railway(s) as leasing partner for locomotives, and the freight railway itself.

The cooperation on shipper' side is limited on the provision of forecasts without further obligations. Their motivation for shippers to participate is regarded as given, although they have no direct benefit<sup>81</sup>.

Difficulties are expected at both freight and passenger railways with regards to leasing activities. On the one hand, both transport modes know distinct peaks in demand, which make this approach potentially highly interesting. Locomotives are an important cost factor and thus even small efficiency improvements are financially relevant. On the other hand, this approach leads to a mutual dependency of leasing partners. Efficiency gains can

<sup>81</sup> For details please refer to chapter 8.5

only be translated in financial profit, if the number of locomotives in proprietary possession is reduced on a level, which is insufficient for certain days of peak demand without leasing additional locomotives. For these days, participating freight and passenger railways rely on each other. Understandably this creates uncertainties about having sufficient locomotives in times needed. The expected scepticism could be encountered with a preliminary “dry run”. The freight railway defines a theoretical limit over which additional locomotives would be needed. Expected traffic volumes from submitted shipper forecasts are compared with this theoretical limit for a predefined period of time. This gives planners a feeling about the potential availability of additional locomotives from the leasing partner. This approach further has the advantage that the quality of submitted forecasts can be validated concurrently.

There are further aspects, which might hinder freight or passenger railways from participation:

*Differing planning horizons at freight and passenger railways*

The railway with the longer planning horizon has an advantage in terms of being able to lease additional assets first. This inequality can be encountered with predefined priority rules.

*Preventive reservation of locomotives in joint safety stock*

Planners at railways could be attempted to reserve locomotives in joint safety stock as soon as there is a slight chance of need. A surcharge on reserved and later freed up locomotives could help minimize this risk.

## **9.4.2 Process Design**

This approach is again illustrated using the example of block train services in the mineral oil sector. The process starts with the submission of standardised and compulsory forecasts from shippers to the freight railway (Figure 9-12 and Figure 9-13). This part is identical with the collaborative approach described in chapter 9.2, having the same time horizon and characteristics of forecasts. In a next step, freight railways aggregate this information to identify possible traffic peaks. If there are weekdays exceeding average daily volumes by a certain percentage (e.g. 20%), additional locomotives are leased from the proposed joint safety stock with a passenger railway (chapter 6.4.3). If there are not enough locomotives available in joint safety stock, possible solutions are sought with the participating passenger railway first. If there is no satisfactory solution, the freight railway requests additional locomotives from the leasing company as last resort.

**Figure 9-12: Design of new process - overview**

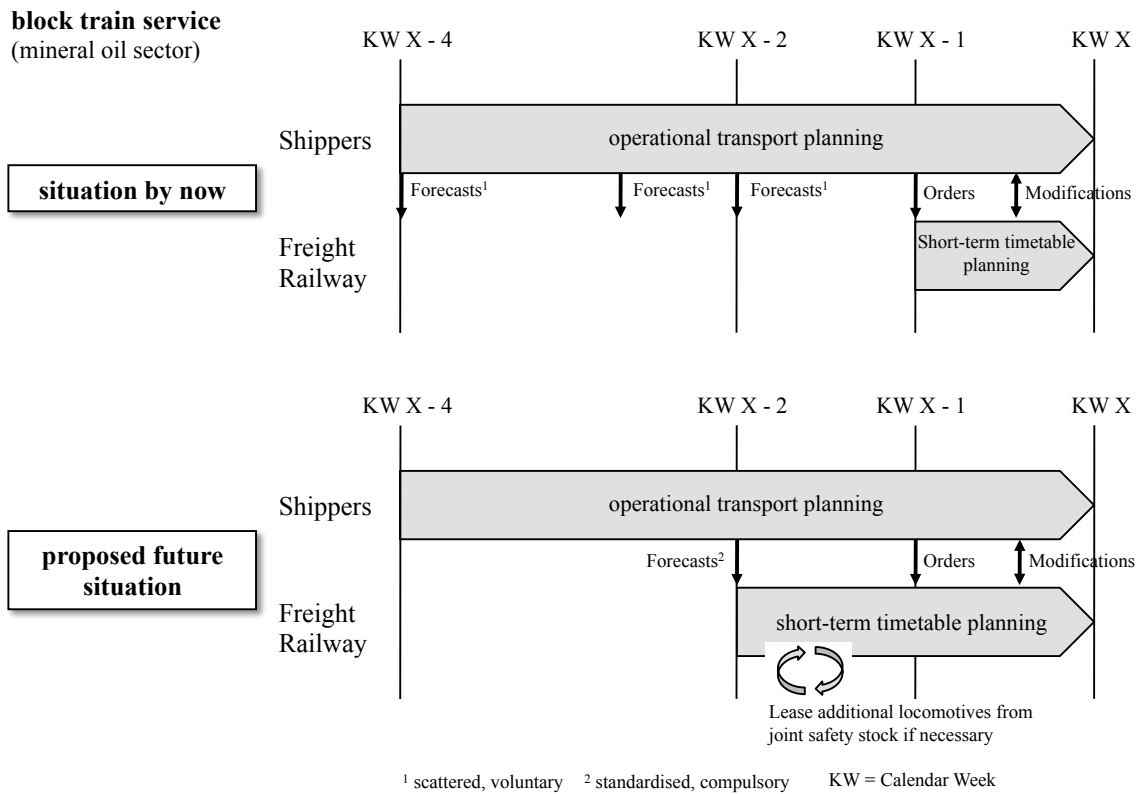
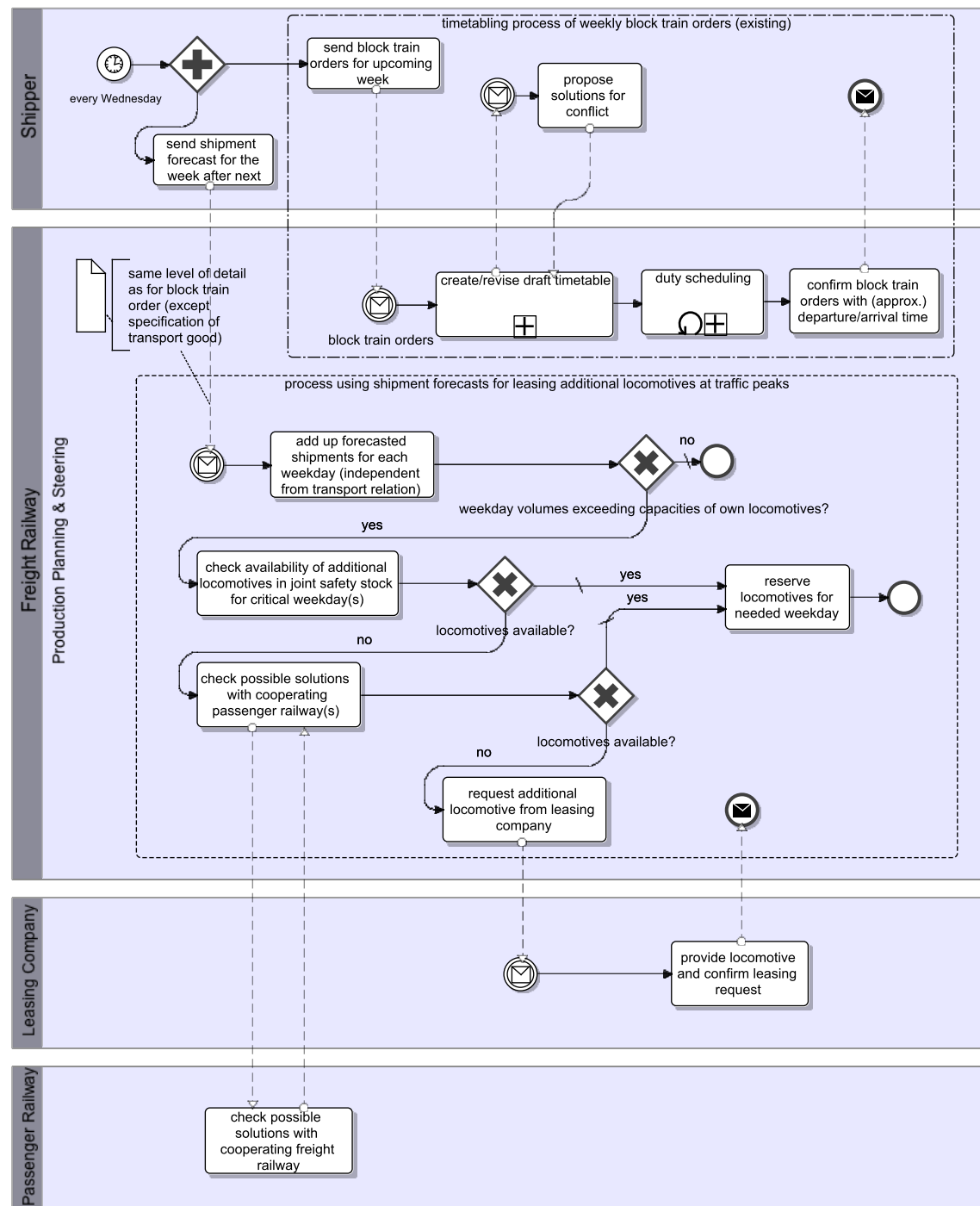


Figure 9-13: Design of new process - details



### 9.4.3 Quantification of Benefit

The benefit from leasing assets at traffic peaks cannot be quantified with efficiency gains only, as leasing costs for locomotives are generally higher than costs for ones in proprietary possession. Additional leasing costs must therefore compellingly be taken into account. The correlation between efficiency gain, leasing costs and overall cost saving is

expressed in the following formula. It neither requires the knowledge about the number of locomotives nor absolute costs of locomotives<sup>82</sup>:

$$a = 1 - \frac{b * x * (1 - y) + b * x * y * z * (1 + c)}{b * x} = y * (1 - z * (1 + c)) \quad (9.1)$$

*a* = cost saving (%)

*b* = costs per locomotive

*c* = additional costs for leased locomotives compared to ones in proprietary possession (%)

*x* = number of locomotives

*y* = reduction of dimensioning level for locomotives in proprietary possession (%)

*z* = proportion of traffic days with needed additional locomotives (%)

The following example demonstrates the principal method for applying formula 9.1 with data from the mineral oil sector<sup>83 84</sup>. The first step is to reduce the dimensioning level for locomotives in proprietary possession so that additional locomotives have to be leased during times of peak demand. In the exemplary case, a target reduction of 10% was assumed. Based on the real distribution of transport volumes over the year, the proportion of traffic days with needed additional locomotives can be determined. In the analysed case, this percentage is at 4%.

Figure 9-14 is the graphical depiction of formula 9.1 with different reduction levels of locomotives in proprietary possession and assumed additional costs of 25% (1) for leased locomotives. With a reduction of locomotives in proprietary possession of 10% and the consequential 4% proportion of traffic days with needed additional locomotives, the cost savings add up to 9.5% (2).

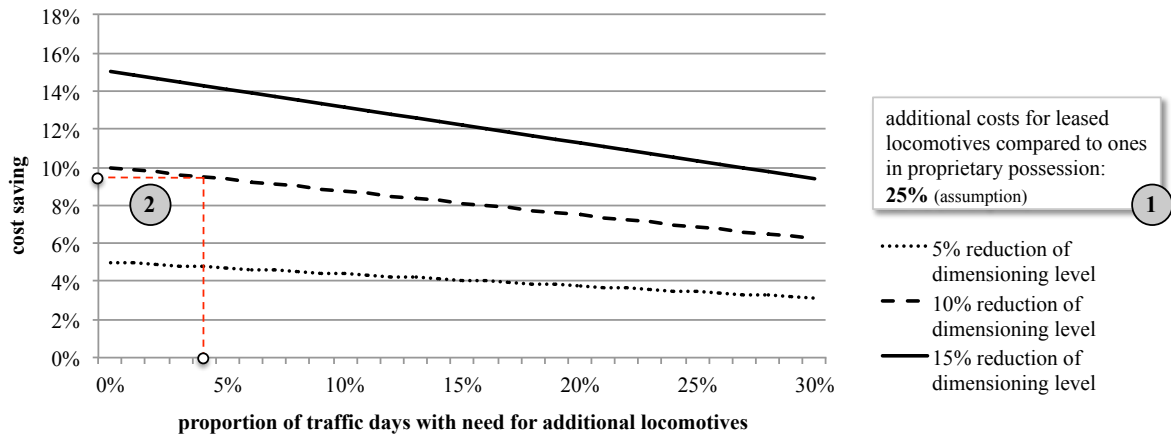
---

<sup>82</sup> The formula simplistically assumes that on traffic days with leased locomotives, initial transport capacities are fully restored. In practice, this will not be necessary in all cases, which is why calculated cost savings tend to be too conservative.

<sup>83</sup> The database is identical with the one applied in chapter 9.2.

<sup>84</sup> Note that for a future implementation of this approach, it will be necessary to have a more comprehensive picture about future shipments before leasing additional locomotives. This requires the analogue integration of other (non-analysed) transport sectors.

**Figure 9-14: Illustration of method for quantifying benefit**



The sensitivity analysis in Table 9-2 about the cost saving potential in function of the three relevant formula parameters leads to the following conclusions:

- The reduction level of locomotives in proprietary possession has by far the most influence on cost saving.
- The proportion of traffic days with needed additional locomotives is little sensitive in the analysed range.
- Nearly irrelevant is the level of leasing costs in the analysed range of the sensitivity analysis. This is highly relevant for the application of this collaborative approach and thus examined more closely.

**Table 9-2: Sensitivity analysis of cost saving potential**

3 →		25%				3 →		50%			
↓ 1 / 2 →	5%	10%	15%	20%	↓ 1 / 2 →	5%	10%	15%	20%		
5%	5%	4%	4%	4%	5%	5%	4%	4%	4%		
10%	9%	9%	8%	8%	10%	9%	9%	8%	7%		
15%	14%	13%	12%	11%	15%	14%	13%	12%	11%		
20%	19%	18%	16%	15%	20%	19%	17%	16%	14%		

3 →		75%				3 →		100%			
↓ 1 / 2 →	5%	10%	15%	20%	↓ 1 / 2 →	5%	10%	15%	20%		
5%	5%	4%	4%	3%	5%	5%	4%	4%	3%		
10%	9%	8%	7%	6%	10%	9%	8%	7%	6%		
15%	14%	12%	11%	10%	15%	14%	12%	11%	9%		
20%	18%	17%	15%	13%	20%	18%	16%	14%	12%		

- 1: reduction of dimensioning level for locomotives in proprietary possession
- 2: proportion of traffic days with need for additional locomotives
- 3: additional costs for leased locomotives compared to ones in proprietary possession

The break-even function for the leasing costs of locomotives can be derived from formula 9.1, when setting parameter  $a = 0$ :

$$a = y * (1 - z * (1 + c)) = 0$$

$$c = \frac{1}{z} - 1 \quad (9.2)$$

$a = \text{cost saving (\%)}$

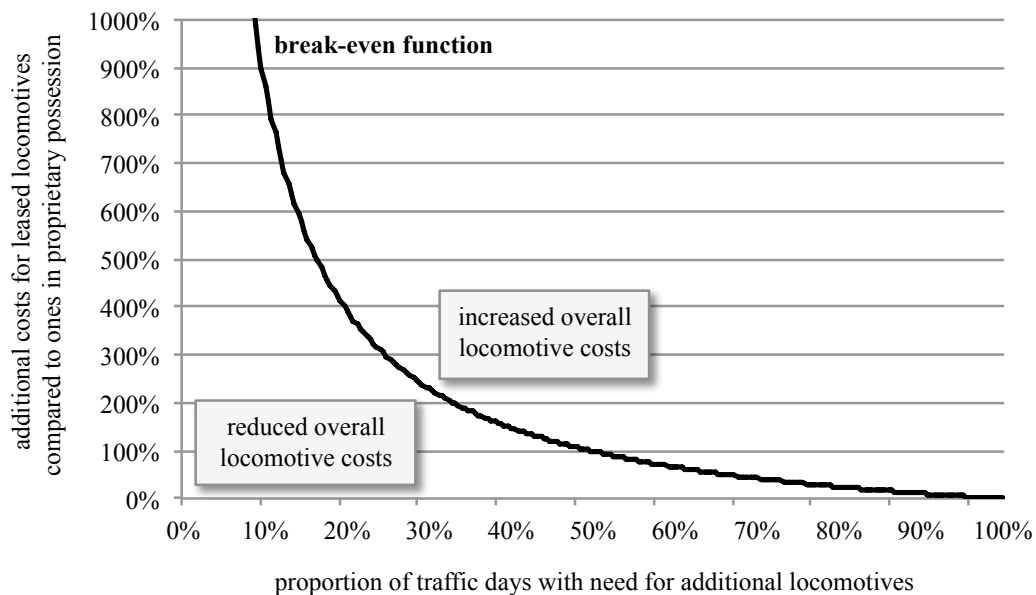
$c = \text{additional costs for leased locomotives compared to ones in proprietary possession (\%)}$

$y = \text{reduction of dimensioning level for locomotives in proprietary possession (\%)}$

$z = \text{proportion of traffic days with needed additional locomotives (\%)}$

Figure 9-15 displays the derived break-even function 9.2 graphically<sup>85</sup>. It shows that if there are only few traffic days at which additional locomotives have to be leased, the possible additional costs for leased locomotives compared to ones in proprietary possession become virtually irrelevant. Decisive is the clause “compared to ones in proprietary possession”. If the current level of locomotive costs is already very low, e.g. due to a large number of fully amortised locomotives, the possible leasing costs in absolute figures are correspondingly low too. In the extreme but theoretical case of a fully amortised fleet of locomotives, leased locomotives would always be more expensive, whatever the leasing rates are. Hence, the higher the costs of the current locomotive fleet are, the more valuable is the quantitative benefit of leasing locomotives at traffic peaks.

**Figure 9-15: Break even function for leasing additional locomotives**



These considerations lead to the overall conclusion that the benefit of leasing additional locomotives at traffic peaks is financially highly attractive in most cases. The critical element is not a matter of given financial benefit but of the availability of locomotives at

<sup>85</sup> The total number of traffic days was set at 250, representing one full year.



times needed. As shown in Figure 9-15, freight railways could accept high leasing rates, as long as the proportion of traffic days with leased locomotives remains below 30%. The possibility to pay high leasing rates could be used to negotiate advantageous priority for leasing requests.

## 9.5 Summary and Recommendation

### *Approach 1 – Using Shipment Forecasts for Joint Levelling Traffic Peaks*

- A financial incentive will have to be granted for shippers postponing their shipments at traffic peaks.
- Transport volumes must have the following characteristics to be suited for this approach: Daily transport volumes are normally distributed over the year and daily variations of transport demand are significantly higher than weekly ones. Both preconditions are given in the mineral oil sector.
- Simulations quantifying the benefit show that traffic peaks are significantly levelled and transport volumes become more equally distributed. A noticeable efficiency gain is therefore expected for locomotives as a result of this collaborative approach.
- Using shipment forecasts for joint levelling traffic peaks is recommended for implementation.

### *Approach 2 – Joint Planning of Feeder Relations with Dominant Shippers*

- It will be rather difficult to gain the general motivation of shippers and the freight railway to implement this collaborative approach. On freight railway side, the approach is associated with a major cultural change in planning philosophy, which could cause fundamental scepticism and opposition. On shipper side, it constricts flexibility without ulterior advantages for shippers. Financial incentives will therefore be necessary to gain the participation of shippers. However, these incentives may cause unwanted behaviours and thus require a close monitoring from the freight railway.
- A high potential for improving the utilisation rate of feeder trains could be identified at one of the two analysed relations. On this feeder relation, implementing the approach would increase the effectiveness of trains significantly. From an overall perspective however, the benefit will remain limited, as a number of conditions have to be fulfilled for applying this approach. This clearly limits an extensive implementation.
- The joint planning of feeder relations with dominant shippers is only partly recommended for implementation. This approach is applicable on few feeder relations only. In all other cases, either basic preconditions are not given or the expected effectiveness gain will be too low to justify the risks, associated with needed incentives.

*Approach 3 – Using Shipment Forecasts for Leasing Locomotives at Traffic Peaks*

- The cooperation between shippers and the freight railway will not cause difficulties. More challenging is the set up of a leasing cooperation between the freight railway and a suitable partner. The key discussions will revolve about the guarantee to get additional locomotives at times needed. In this regard, a passenger railway is regarded as the most promising partner. The service of specialised leasing companies could be used as last resort.
- The highest efficiency gain is achieved, if there are only a few days with distinct traffic peaks during the year. In this case, a significant cost saving potential could be realised even with high leasing rates. It presupposes however that the locomotive fleet at the freight railway is not largely amortised.
- Using shipment forecasts for leasing locomotives at traffic peaks is strongly recommended for freight railways, notably for those having a modern fleet of locomotives.

Figure 9-16 summarises the major findings of this study in a highly aggregated form. Collaborative approaches 1 and 7 fulfil all requirements for implementation and should thus be approached with priority. The benefit of the collaborative approach 6 turned out to be clearly limited. Collaborative approaches 2, 5, 8, and 9 are worth to be pursued in more detail, as either on the freight railway or shipper side the requirements for a successful implementation are fulfilled. In turn, the chance for a successful general implementation is rather questionable for collaborative approaches 3 and 4.

**Figure 9-16: Summary of results**

No	Collaborative Approach	(1)	(2)			(3)
			A	B	C	
1	Using shipment forecasts for joint levelling traffic peaks	Green	Green	Red	Not applicable	Green
7	Using shipment forecasts for leasing rolling stock and train drivers at traffic peaks	Green	Green	Red	Not applicable	Green
6	Joint planning of feeder relations with dominant shippers	Green	Not applicable	Not applicable	Green	Yellow
2	Using shipment forecasts for optimising timetables and duty schedules	Green	Yellow	Red	Not applicable	White
9	Forecast on leasing duration for booked freight wagons	Yellow	Not applicable	Not applicable	Green	White
5	Capacity planning of single-wagonload trains	Yellow	Not applicable	Not applicable	Green	White
8	Using shipment forecasts for adjusting availability of locomotives to actual demand	Yellow	Green	Red	Not applicable	White
3	Placing shipment orders with flexible due dates	Yellow	Yellow	Red	Not applicable	White
4	Taking charge of shipper's freight wagon scheduling	Yellow	Yellow	Red	Not applicable	White
10	Publishing unused shipment time slots for block trains	Red				
11	Forecast on releasing time of booked freight wagons	Red				
12	Early delivery of empty wagon bookings	Red				

*(1) Value of collaborative approach for freight railway (chapter 6)*

- expected productivity gain disproportionately high to risks & costs
- expected productivity gain proportionately to risks & costs
- expected productivity gain disproportionately low to risks & costs

*(2) Qualification of analysed sectors for collaborative approaches (chapter 8)*

- qualify for collaborative approach
- partly qualify for collaborative approach
- not qualified for collaborative approach

*(3) Case studies for collaborative approaches (chapter 9)*

- implementation recommended
- implementation partly recommended
- implementation not recommended

A = Mineral Oil Sector; B = Gravel Sector; C = Steel Scrap Sector     not applicable     no case studies conducted

# 10 Concluding remarks and perspectives for further research

---

## 10.1 Summary of key results

The study has asked the research question of what is the potential of operational collaborations between shippers and freight railways and how they affect freight rail productivity. The answers to the detailed questions derived from this consideration are summarized in the following.

***Which operational processes are relevant for productivity at freight railways and would profit from collaborations with shippers? What information is needed at what time and in which quality?***

The study identified 28 requirements for achieving high productivity at freight railways, of which half can be influenced by operational planning processes (Table 5-1). Operational planning processes therefore play an important – but not exclusive – role for achieving high productivity at freight railways. The most relevant ones are short-term timetable planning and the leasing of rolling stock and personnel, followed by preventive maintenance planning, planning of vacation, overtime and time off in lieu, and distribution planning of empty wagons.

Although empirical analyses have shown that nearly all of the aforementioned processes would profit from operational collaborations with shippers, the most promising approaches are found at short-term timetable planning and the leasing of locomotives and train drivers (Table 6-2). In many cases, the exchange of (forecast) information already suffices to help responsible planners improve freight rail productivity (Figure 6-8).

Analyses in chapter 6 revealed that needed shipper information strongly depends on the intended use at the freight railway and considerably differs in terms of accuracy, time horizon and level of detail (Table 6-2). This underlines the fundamental necessity of having a precise knowledge about what information shippers are able to provide and in which quality.

The hypothesis in chapter 3.1 was that a lack of operational collaborations hampers an efficient and effective planning at freight railways. This hypothesis can be sustained based on the empirical process analyses in chapter 6. Operational collaboration between shippers and freight railway is generally limited on the shipment ordering process and subsequent modifications. Some shippers also provide regular shipment forecasts on a voluntary basis (chapter 8.2.2.5). However, these forecasts are of little value for the

freight railway, as they cover a minor part of total traffic volumes only and thus neither allow an early determination of traffic peaks nor can they be used for detailed timetable scheduling (chapter 6.2.2).

***How is transport planning performed on shippers' side? What information is available at what time and in which quality? What affects planning quality?***

The analyses on shippers' side focused on the three commodities mineral oil, gravel, and steel scrap. Their standard deviations of weekly transport volumes and shares of regular traffic show that they are particularly challenging for transport planning (chapter 8.1).

In the mineral oil sector, operational rail transport planning is typically divided in a rolling monthly planning process and an event-driven short-term planning process (chapter 8.3.2.4.1). Analysed data proved that accurate and detailed monthly forecasts are possible under certain conditions (chapter 8.2.2.5). At the same time, some shippers are not even able to place accurate shipment orders. This heterogeneity can be largely explained by five major characteristics, which strongly affects planning quality (chapter 8.2.3.2). Taking these characteristics into account, a large majority of shipments is expectedly predictable in the mineral oil sector with a time horizon of 2-3 weeks and an average forecast accuracy between 80% and 90%.

In the gravel sector, operational rail transport planning is done on a weekly basis with a planning horizon of one week (chapter 8.3.2.4.1). Shippers thus hardly know more than the freight railway. As a consequence, shippers do not provide any shipping information exceeding a weekly time horizon. Even this information is subject of significant uncertainty (chapter 8.3.2.5). Empirical results indeed show that general conditions are in sum highly negative for accurate and far-reaching transport plans in the gravel sector (chapter 8.3.3.2). No valid forecasts can therefore be expected and the potential for operational collaborations consequently remains little.

In the steel scrap sector, operational transport planning is basically a day-to-day activity with a time horizon of few days only (chapter 8.4.2.4). Transport responsibility between buyer and seller of steel scrap as well as the procurement process show particularities, which have a significant impact on transport planning (chapters 8.4.2.2 and 8.4.2.3). Numerous characteristics suggest that accurate transport forecasts as well as balanced daily shipments are possible (chapter 8.4.3.2). However, a transfer of transport planning competences from individual suppliers of steel scrap to one single actor of the supply chain network would be necessary for that. Contractual relationships and market forces will make it difficult to enforce a change of current situation in this sector.

The hypothesis in chapter 3.2 was that transport sectors dispose of unshared planning information, which are valuable for freight railways. The results of this study only partly support this hypothesis. The prerequisites for operational collaborations are not always given. Further the situation is highly specific between and sometimes even within different transport sectors. This allows no cross-sectoral conclusions and recommendations.

***Which forms of operational collaborations qualify to be implemented between shippers and freight railways and what is the effect on freight rail productivity?***

The study identified and assessed in total twelve potential forms of collaborative approaches (Figure 9-16). Nine of them focus on the exchange of (forecast) information, notably from shipper to carrier (Figure 6-8). The remaining three approaches are more intense forms of collaborations such as joint or delegated planning. Identified collaborative approaches notably improve the efficiency of locomotives and train drivers, by helping responsible planners create denser duty schedules, reduce unproductive transfers, and strengthen the demand-oriented availability of rolling-stock and personnel. Approaches improving the effectiveness are less frequent and notably focused on increasing the utilisation rate of single wagonload trains.

From the perspective of a freight railway, three out of the twelve collaborative approaches are clearly not recommended for implementation, as expected productivity gains would be disproportionally low compared to risks and costs. These are publishing unused shipment time slots for block trains, demanding forecasts of the releasing time of booked wagons and the early delivery of empty wagon bookings, based on forecasted train utilisation rates. Two particularly promising collaborative approaches are the use of shipment forecasts for the joint levelling of traffic peaks and for the leasing of locomotives at traffic peaks. Under the assumptions made, conducted case studies indicate a significant productivity gain and suggest a feasible implementation (chapters 9.2.3 and 9.4.3). Further collaborative approaches, which ought to be pursued for implementation are capacity planning of single wagonload trains, the use of forecasts on leasing durations for booked freight wagons, and the integration of shipment forecasts for adjusting the availability of locomotives in proprietary possession to actual demand.

These results confirm the hypothesis in chapter 3.3 that there are implementable forms of operational collaborations between shippers and freight railways, which have a positive effect on freight rail productivity.

## **10.2 Concluding remarks**

Overall, the study could show that there is a number of implementable forms of operational collaborations between shipper and freight railway in Switzerland, which help increase freight rail productivity. However, the potential is not equally given for all transport sectors, due to heterogenic transport planning processes and determinants. This makes sector-specific forms of collaborations necessary. Further, the productivity gain of many collaborative approaches progressively increases in relation to covered overall shipping volumes at the freight railway. In this regard, the study's focus on three transport sectors turned out to be a limiting factor for quantifying the productivity gain.

The highly specific circumstances between and even within analysed transport sectors suggest that elaborated sector-specific results and collaborations will not be transferable to other transport sectors. However, the disclosed cause-effect-relationships of

determinants in transport planning on the ability and quality of transport forecasts at shippers is a valuable information for better assessing the situation in other transport sectors. In addition, elaborated framework of determining influencing factors on transport planning at shippers is explicitly designed for any kinds of commodities and transport sectors and thus well transferable. Hence, analogue research on further transport sectors is now feasible with a uniform and coherent approach. The framework is furthermore easily expandable with additional features and values, if necessary.

The business model of the freight railway is relevant for the transferability of the results, insofar as not all depicted planning processes have to exist at freight railways. An example would be the business decision to offer traction services without providing freight wagons. In this case, several collaborative approaches and challenges revealed in this study become irrelevant. In case of a similar business model though, the main procedures and challenges of depicted operational processes will be transferable with a high probability to other freight railways as well.

Eventually, this study provides an integrated and coherent depiction of operational rail transport planning at both shippers and freight railway, revealing general capabilities, challenges and determinants on transport planning in Switzerland. This knowledge contributes to a better general understanding of rail freight activities on the operational level and can provide valuable inputs for other fields of rail freight research, as well as help validate the applicability of research results in practice.

### **10.3 Perspectives for further research**

This study focused on three transport sectors in Switzerland, which are particularly challenging for planning. For being able to evaluate the benefit and implementation of collaborative approaches more accurately in a cross-sectoral perspective, further research on other transport sectors will be necessary. Notably for implementing collaborative approaches in single wagonload services, transport planning processes and restrictions must be considered integrally for numerous transport sectors. The elaborated framework in chapter 7 provides a well-structured basis for doing this in a systematic and comparable way.

To keep the study focused and comparable with analyses on shippers' side, the research explicitly focused on the dominating freight railway in Switzerland. Hence, this research cannot draw conclusions on country-specific differences in operational planning of freight railways and potentially differing approaches with regards to operational collaborations with shippers. A comparative analysis of operational planning processes with different European freight railways would help answer this open research questions. It could provide the basis to determine best practices in operational planning among European freight railways and to develop strategies for implementing successful forms of collaborations internationally.

## Appendices

### Appendix A – Description and evaluation of possible process modelling methods







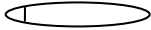
#### A.1. Event-driven process chain

The event-driven process chain (EPC) is an important notation to describe business processes graphically in a semiformal way [NÜTTGENS (2008)]. It was developed along with ARIS at the Saarland University in close collaboration with SAP AG.

EPC models depict business processes as a logical chronology of business tasks. The “lean” event-driven process chain only includes the basic elements of functions, events and joined operators (Table A.1). The process always starts with an event, which triggers a certain function. This function produces new events, which may again start additional functions. Events are passive elements in the sense that they do not provide decisions. Functions on the other hand are the active elements within EPC, as they take input and transform it to output. Functions can also make decisions that influence the behaviour of the process. The process logic in EPC is given by connectors called joined operators (“and”, “or”, “either or”) and shows the causal relations between functions and events.

The extended event-driven process chain (eEPC) expands the “lean” EPC with other elements such as organisational units or data objects, which are graphically associated to a certain function. Figure A.1 shows an eEPC using the example of a simplified sales order processing.

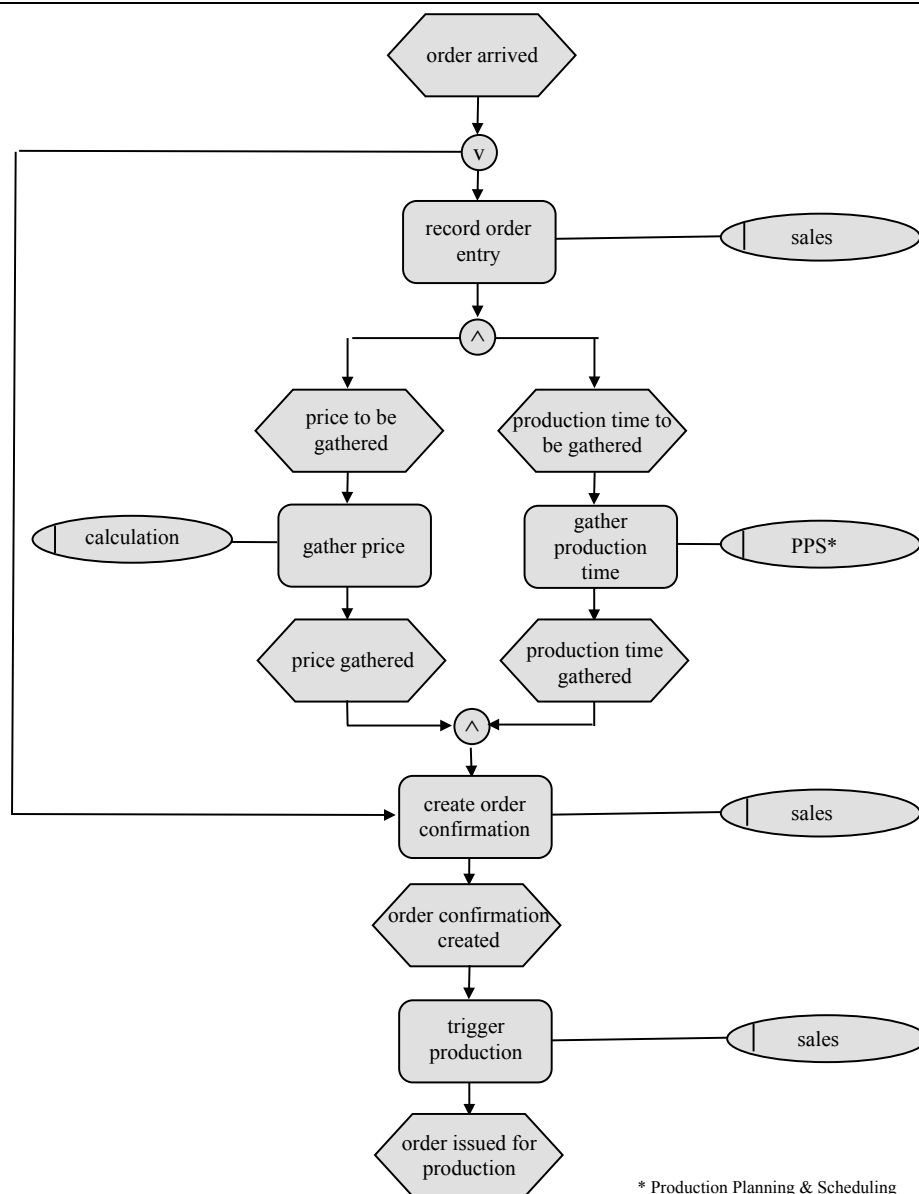
**Table A.1: Core elements of eEPC**

Symbol	Name	Meaning
	Event	An event can be either a trigger to start a function or result of a finished function.
	Function	A function stands for a certain task or process which has to be accomplished to reach the next event.
	Joined Operation	 = and;  = or;  = either or
	Organisational Unit	An organisational unit stands for a department or person which is responsible for a certain function

Source: WESKE (2007)



Figure A.1: Example process described with eEPC



Due to their semiformal nature, eEPC leaves process designers a certain degree of freedom when modelling business processes [WESKE (2007)]. The main focus is rather on representing graphically concepts and processes than their formal aspects or their technical representation. This leads to an intuitive and easy readable notation. Nevertheless, eEPC is often not the appropriate method to describe business processes graphically. This is because even simple processes become quickly confusing and overcrowded, due to the explicit description of all events and the separate graphical illustration of data objects and organisational units [SCHÖNSLEBEN (2001)]. Questionably is furthermore the information content of events since they are mostly already implied in the function descriptions. That is also why newer versions of the ARIS-toolset allow suppressing the events [THURNER (2004)].

Taking these considerations into account, the use of the extended event-driven process chain does not seem to be the appropriate modelling method for this study.

## **A.2. Activity diagram in UML**




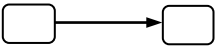
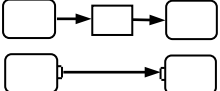
The activity diagram is defined in OMG's Unified Modeling Language (UML) as one of thirteen different types of diagrams<sup>86</sup>. UML was developed in the late nineties by BOOCH ET AL. (2006) to simplify and consolidate the large number of object-oriented development methods that had emerged. UML is a general-purpose visual modelling language, which is used to specify, visualize, construct, and document the elements of a system [RUMBAUGH ET AL. (2005)]. It includes semantic concepts and notation as well as guidelines. The activity diagram within UML is a representative of one of the few predominantly non-object-oriented notations. They are mainly used for modelling dynamic aspects of a system. The notation of activity diagrams is influenced by various sources because there was no dominant business process modelling language at that time.

Activity diagrams depict the control flows from activity to activity. They are similar but much more powerful than traditional flow charts, because they allow not only sequential but also concurrent control. The basic elements of activity diagrams are activity states, transitions, and decisions (Table A.2). Activity states are represented by activity nodes, which describe the execution of a statement in a procedure or the performance of a step in a workflow. These nodes are connected by control or data flows. Activity diagrams may also contain branches (decisions) and forking of controls into concurrent strings. The leaves of an activity graph are called actions. An action is a basic, predefined activity, such as modifying attribute values, creating or destroying objects, and sending signals. Time elements can be indicated in constraints, which are displayed with curly braces. Ultimately the introduction of vertical swim lanes representing organizational units improves the visibility significantly.

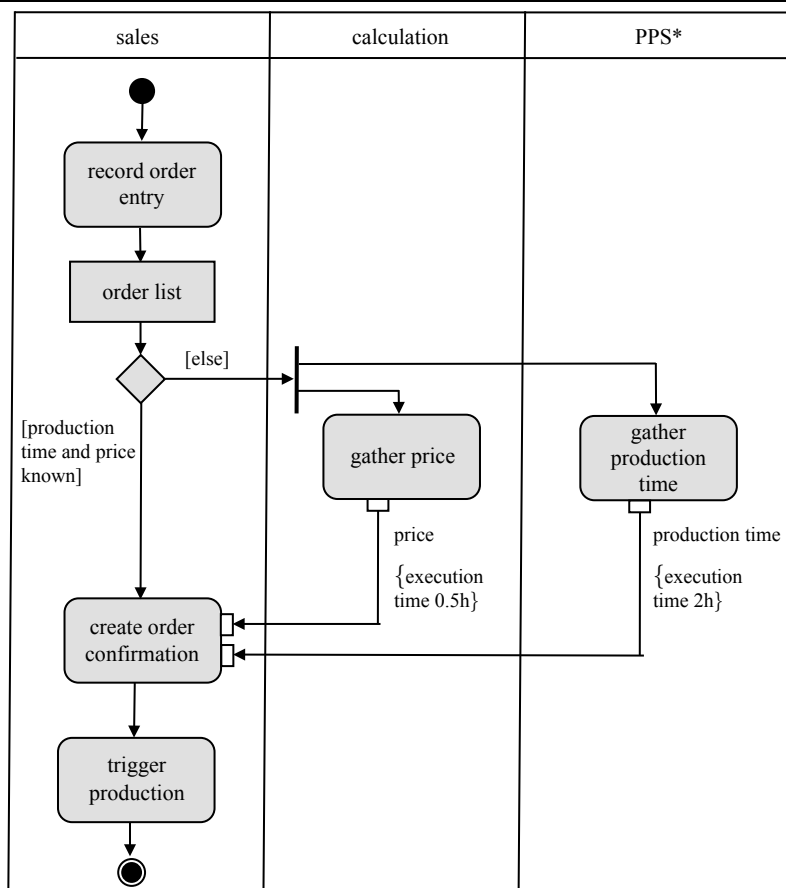
---

<sup>86</sup> [www.omg.org](http://www.omg.org)

**Table A.2: Core elements of UML activity diagrams**

Symbol	Name	Meaning
	Object Node	Object nodes hold data temporarily as they wait to move through the graph.
	Activity Node	An activity node represents the execution of a statement in a procedure or the performance of a step in a workflow.
	Decision Node / Merge Node	A decision node is used for specifying different alternatives of the original path under different conditions. A merge node brings multiple alternate flows together.
	Control Flow	A control flow connects activity nodes to indicate that the activity at the end of the edge (arrowhead) cannot start until the source activity has finished.
	Object Flow	An object flow is an edge for data passing.

Source: BOOCH ET AL. (2006)

**Figure A.2: Example process described with UML activity diagram**

\* Production Planning & Scheduling

Activity diagrams primarily show the flow of processes. Therefore, they are well suited for the behavioural description a system. Activity diagrams are easily understood and can

additionally act as a bridge to more object-oriented diagrams such as sequence diagrams within UML.





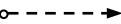


Activity diagrams can become though very complicated, when complex systems have to be modelled. Another weakness is the lack of symbols to describe basic control structures such as repetitions or multiple choices [BALZERT (2008)].

### **A.3. Business Process Modelling Notation**

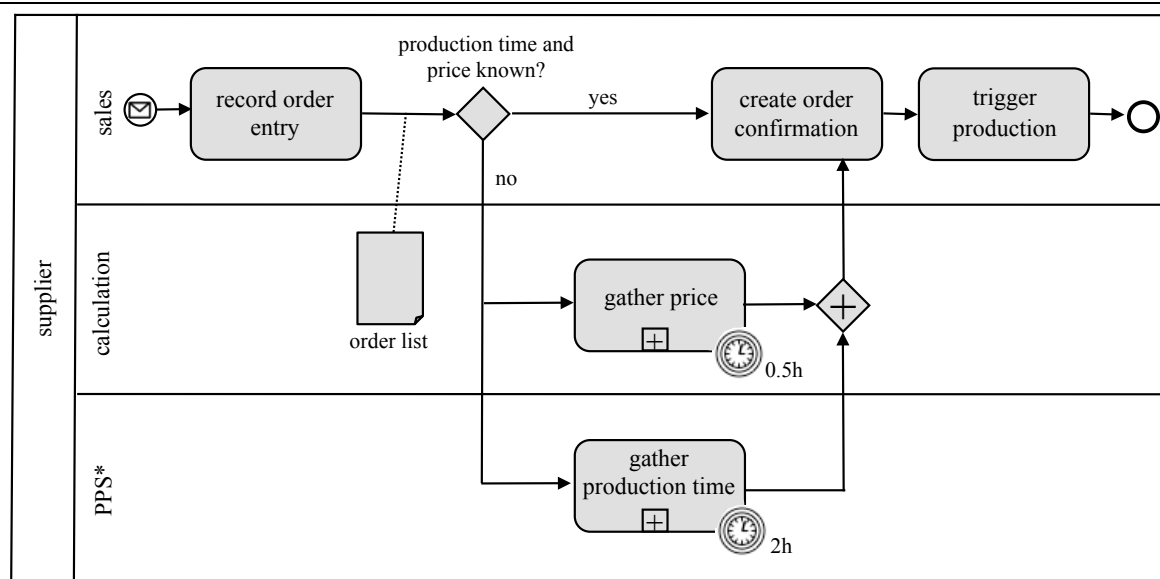
Business Process Modelling Notation (BPMN) is a “flow chart-based notation for defining business processes from the simple to the more complex and sophisticated models required to support process execution” [WHITE AND MIERS (2008)]. The Notation Working Group, formed in August 2001 and composed of 35 modelling companies, organisations and individuals, released in May 2004 the first BPMN 1.0 specifications to the public. They used elements of both UML activity diagrams and event-driven process chains together with other modelling languages to develop BPMN [WESKE (2007)]. The intent of BPMN for business process modelling is very similar to the intent of UML. It wants to identify the best practices of existing approaches and to combine them into a new, generally accepted language. The primary goal of BPMN is “to provide a notation that is readily understandable by all business users, from the business analyst that create the initial drafts of the processes, to the technical developers responsible for implementing the technology that will perform those processes, and finally, to the business people who will manage and monitor those processes” [OMG (2009)].

BPMN is similar to UML activity diagrams in many respects. The elements used in BPMN can be classified in flow objects, connecting objects, swimlanes, and artefacts. The three basic flow objects are event, activity, and gateway (Table A.3). An event is something that “happens” during the course of a process. They can start, delay, interrupt, or end the flow of the process. An activity represents the work performed within a business process. It usually requires some type of input and produces some sort of output. Activities are either atomic, representing the lowest level of detail in the diagram, or compound. Compound activities are also called sub-processes as they can be drilled down to see a more detailed level of the process. Gateways control how the process diverges or converges. They split and merge the flow of a process. Internal markers inside the basic diamond shape indicate different types of gateways. Exclusive gateways require a decision for one path, while parallel gateways start all outgoing paths in parallel. Swimlanes partition and organise activities in a diagram. There are two main types: Pools and lanes. Pools act as a container for a process, each representing one participant. A participant is defined as a general business role and references to business-to-business collaborators such as buyer, shipper, or seller. Lanes are additionally used for a more detailed partition within pools.

**Table A.3: Core elements of BPMN**

Symbol	Name	Meaning
	Activity	An activity is a generic term for work that a company performs. Tasks and sub-process are types of activities. Sub-processes are marked with a little “plus sign”, placed in the lower centre of the shape.
	Event	An event is something that happens during the business process. There are three types of events, based on when they affect the flow: Start, Intermediate, and End
	Gateway	Gateways are modelling elements that control how the process diverges or converges. A gateway can split and/or merge a sequence flow.
	Sequence Flow	A sequence flow is used to show the order of flow objects (activity, event, gateway) in a process.
	Message Flow	A message flow is used to show the flow of messages between two participants, represented by two separate pools in a diagram.
	Artefacts	Artefacts capture additional information about a process, beyond the underlying flow-chart structure. The standard artefacts are data objects, groups, and text annotations.
	Swimlanes	Swimlanes partition and organise activities. There are two main types: A “Pool” represents a participant in a process. It can be divided into different sub-partitions, called “Lanes”.

Source: WHITE AND MIERS (2008)

**Figure A.3: Example process described with BPMN**

\* Production Planning &amp; Scheduling

BPMN distinguishes three different standard artefacts: text annotations, groups, and data objects. Artefacts capture additional information about a process. Groups highlight and

categorize a section of the model whereas text annotations add further descriptive information to a model. Data objects represent the documents and data that are manipulated by the processes. Artefacts do not directly impact the flow chart characteristics of a process. This aspect shows the strong process-oriented approach of BPMN as data objects are only classified as artefacts. Finally, connectors link the flow objects on a diagram. By definition, sequence flows define the order of flow objects within a participant. Message flows are applied to show the flow of communication between two participants.

BPMN is a process-oriented language designed for easily modelling business processes. BPMN has for one a familiar and easy basic graphical notation, but also complex and advanced features. Their diagrams are well comprehensible due to the categorization of the types of graphical elements and the support for aggregation of Activities.

Several aspects are not well covered however. For instance, BPMN has its limitations, when it is applied for more object-oriented domains. OMG (2009) mentions that “data objects are considered artefacts because they do not have any direct effect on the sequence flow or message flow of the process, but they do provide information about what activities require to be performed and/or what they produce”. WESKE (2007) regards this as questionable, because data objects can in fact have implications on the flow of the process. The data object representing the amount of a credit request does most probably have implication on the procedure that will be required for instance. A second weakness is the restriction that message flows are only possible *between* pools. Message communication though is also often done *within* organisations and should therefore be expressible as well.

## **A.4. Comparative Evaluation**

Event-driven process chain has already been judged as inappropriate for the purpose of this study. However both UML Activity Diagram and BPMN are conceivable as their notations are both standardised and consist of various modelling elements allowing process-oriented modelling of complex systems.

NYSETVOLD (2006) has done a comparison of BPMN and UML Activity Diagram (UML-AD) by grading 32 generic requirements. BPMN has overall achieved a higher score than UML-AD. Specifically BPMN has – according to this study – a better formal semantics and is easier to learn. It is also more flexible in precision. UML-AD on the other hand can link elements in the process model better to a data model. Most requirements however have been graded equally, which shows the high similarity of these two modelling languages.

WHITE (2004) has also reviewed the two modelling notations by comparing 21 patterns that describe the behaviour of business processes. He demonstrated that both notations could adequately model most of the patterns. The fact that both notations share many of the same shapes for the same purposes shows how close the notations are in their

presentation. The variations between the two diagrams exist primarily because of their different target users. The BPMN effort started to create a notation for business people to use. The UML effort started a few years earlier to standardize the modelling of software development and the Activity Diagram was included as part of that effort. That is why Activity Diagrams are compared to BPMN Models still more technical oriented.

Taking the above described strengths and weaknesses into account, BPMN is considered as the more appropriate modelling method for this study. For one, BPMN is regarded as very comprehensible and intuitive. For another, it has a good formal semantics including advanced modelling features. Its weakness concerning the description of data objects is of little relevance, as this study predominantly focuses on business processes rather than data flows.

## Appendix B – Derivation of indicators describing productivity at freight railways

### B.1 Generic Framework

#### B.1.1 Groups of Generic Indicators

This study has defined productivity as “the efficiency and effectiveness with which resources are utilized to produce a valuable output”, efficiency as “the ratio of actual outputs to actual inputs”, and effectiveness as “the degree to which the actual output of the system correspond to its desired outputs” (chapter 2.3.1).

These definitions specify the general term *output* as *consumed output* and *actual output*. This distinction is of little importance for most storable commodities, because the actual output can usually be stockpiled for consumption [LAN AND LIN (2006)]. However, freight rail transport services are typical non-storable commodities, where a surplus of actual output at low demands cannot be stored for the use at high demands. This particularly applies for single wagonload services, where a regular train schedule is offered to customers. If customers consume the actual output (e.g. in terms of train-km) immediately, the actual output is transformed in a consumed output (e.g. in terms of net tons-km). Otherwise, the actual output exhausts and is wasted.

With regards to the widely used partial-factor productivity indicators in scientific literature and industry, consumed outputs as well as inputs can be expressed with either physical or financial terms<sup>87</sup>. Table B.1 shows this classification together with illustrative examples.

**Table B.1: Generic types of input and output elements**

Generic elements		Examples	
input		<b>(physical) input</b>	number of locomotives, number of train drivers, ...
		<b>costs</b>	locomotive costs, train driver costs, ...
output	actual output	<b>actual output</b>	train-km, ...
	consumed output	<b>(physically) consumed output</b>	net tons-km, ...
		<b>revenue</b>	transport revenue, ...

The combination of these five input and output elements leads to 10 generic indicators. Although not all of them correspond with the definition of productivity, they might be of importance for describing potential dependencies. An exception is the non-dimensional

<sup>87</sup> Compare e.g. OUM AND WATERS (1999), WIEGMANS ET AL. (2007), LAN AND LIN (2006), or CHRISTOPH ET AL. (2006)



indicator “revenue per costs”, which clearly corresponds to the definition of profitability [THOMMEN (2008)]. This leaves a set of nine generic indicators (Figure B.1).

**Figure B.1: Groups of generic indicators**

①	$\frac{\text{revenue}}{\text{input}}$	④	$\frac{\text{consumed output}}{\text{actual output}}$	⑦	$\frac{\text{revenue}}{\text{actual output}}$
②	$\frac{\text{costs}}{\text{consumed output}}$	⑤	$\frac{\text{actual output}}{\text{input}}$	⑧	$\frac{\text{revenue}}{\text{consumed output}}$
③	$\frac{\text{consumed output}}{\text{input}}$	⑥	$\frac{\text{costs}}{\text{actual output}}$	⑨	$\frac{\text{costs}}{\text{input}}$

### B.1.2. Dependencies

Partial-factor indicators itself have a limited informative value and must always be interpreted in context [JUNG (2006)]. Hence it is important to have a hierarchical system, showing the logical dependencies of indicators. PREISLER (2008) distinguishes two basic types of ratio systems: Classifying ratio systems and computing ratio systems. Classifying ratio systems connect partial-factor indicators on the basis of their contextual rather than mathematical connections. This approach is highly flexible and allows connecting indicators with no mathematical correspondence. Computing ratio systems connect partial-factor indicators in a factual *and* mathematical sense<sup>88</sup>. They typically follow a top-down approach, starting from the most aggregated indicator and separating it mathematically in more detailed ones. The result is typically a pyramidal structure. This basic idea of computing ratio systems is used in the following to reveal the dependencies of the nine identified partial-factor indicators in the previous chapter. The possibility of dedicating certain indicators to distinct organisational unit is taken as starting point. Such indicators are regarded as grounds for more aggregated indicators and should therefore be identified first. Indicators 4, 5, 8, and 9 in Figure B.1 meet this criterion

Indicator 5 is in the responsibility of the production department. It controls the main adjusting levers for the efficient employment of input to produce the target output. However, the production department does not control whether the actual output is effectively consumed or not. This challenge belongs to business planning and is expressed in indicator 4. This unit defines what is to be produced in which quantity on the basis of expected sales and customer requirements. The unit of business planning is therefore

<sup>88</sup> An example of a widely used computing ratio system is the “Du-Pont-Pyramid”, which has originally been developed for financial controlling in the early 20<sup>th</sup> century. For more details about this and other well-established ratio systems please refer to PREISLER (2008).

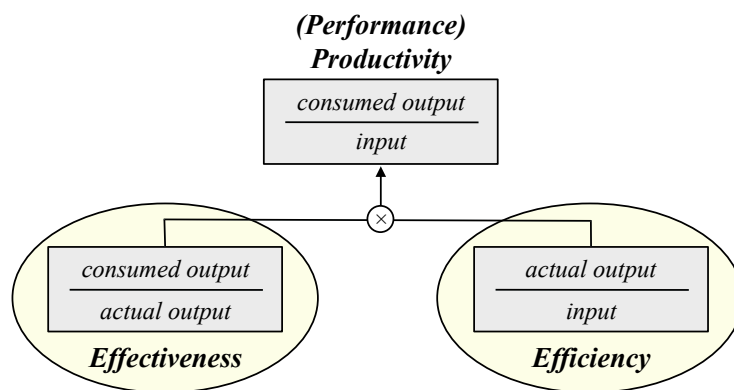
responsible for whether the actual product or offered network is consumed in the foreseen quantity or not.

The sales department has a different focus. Its main objective is to generate a maximum of revenue for each consumed output within the range defined by the unit of business planning. This goal is expressed in indicator 8. This figure does not correspond with the basic definition of productivity, as no input resource is included. However, this indicator is a fundamental factor for partial-factor productivity indicators using revenue as output.

Indicator 9, the fourth independent indicator, is an indicator for unit costs. It clearly belongs to asset management (concerning rolling stock) and human resources (concerning employees). These organisational units control the main levers for influencing this indicator, such as the renewal, leasing or maintenance strategies for rolling stock and the salary policy for employees. Although indicator 9 does not correspond with the basic definition of productivity neither, it is a fundamental factor for partial-factor productivity indicators using costs as input.

These four basic indicators will now be connected with the remaining indicators. As defined earlier, productivity is a product of high effectiveness and efficiency. Indicator 4 is in line with the definition of effectiveness, while indicator 5 corresponds to the definition of efficiency. The mathematical multiplication leads to indicator 3, depicting productivity in a sense of physical performance with no financial elements (Figure B.2).

**Figure B.2: Productivity as product of efficiency and effectiveness**

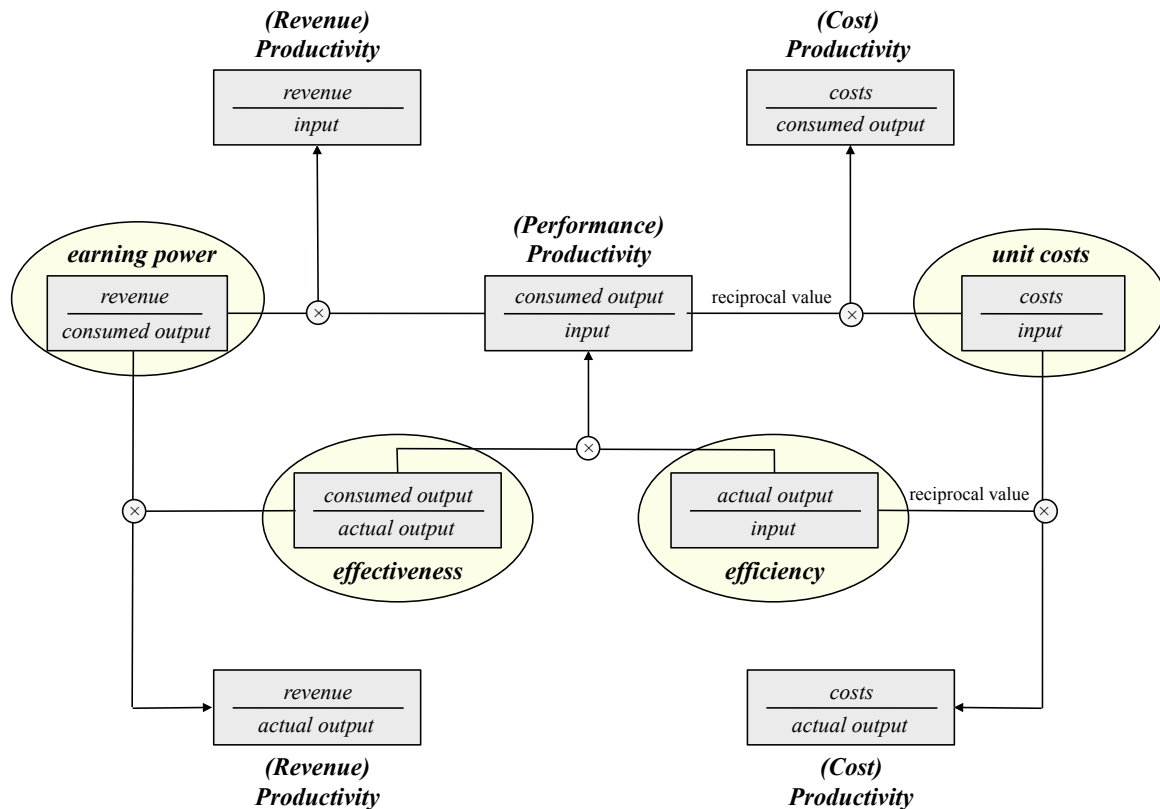


The integration of the remaining indicators is done analogically. Indicator 1 – revenue per input – depicts productivity with a financial output element. It is the mathematical product of indicator 1 (earning power) with indicator 3 (performance productivity). Indicator 7 is formed analogically by multiplying indicator 1 (earning power) with indicator 4 (effectiveness).

These dependencies are similar, when using costs as input element. Indicator 2 – costs per consumed output – depicts productivity by means of a financial input element. It is the reciprocal mathematical product of indicator 9 (unit costs) with indicator 3 (performance productivity). Analogically, indicator 7 is the reciprocal mathematical product of indicator 9 (unit costs) and indicator 4 (efficiency).

The result is depicted in Figure B.3. It shows, that all types of partial-factor productivity indicators can actually be derived from the four basic generic indicators efficiency, effectiveness, earning power, and unit costs.

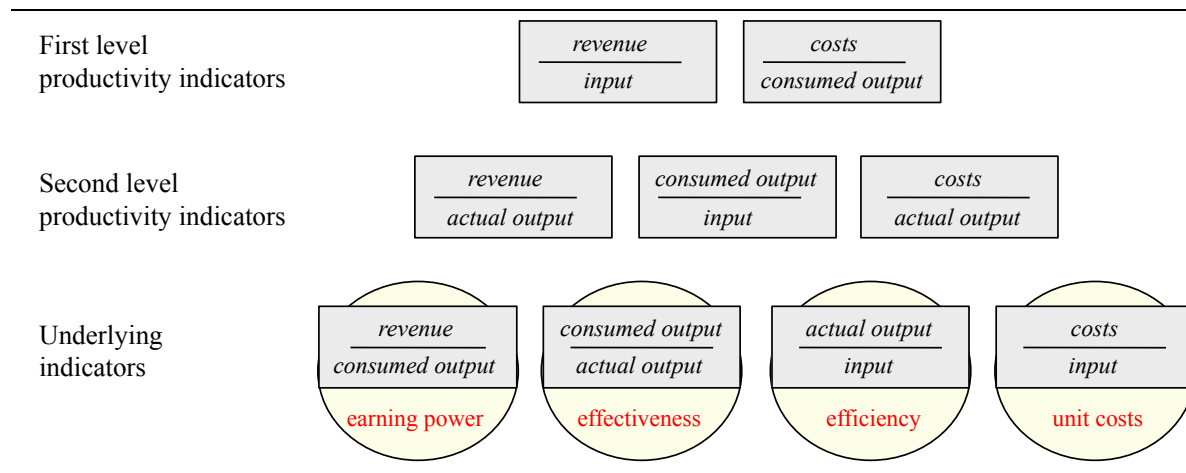
**Figure B.3: Dependencies of identified generic indicators**



### B.1.3 Hierarchical structure

Based on the dependencies of partial-factor productivity indicators, a hierarchical structure of partial-factor productivity indicators can be deviated by counting the number of involved basic indicators efficiency, effectiveness, earning power, and unit costs. Indicators comprising three basic indicators are classified as first-level productivity indicators. Likewise, second-level productivity indicators comprise two basic indicators. The four basic indicators itself represent the most detailed level.

The consequential hierarchical structure in Figure B.4 facilitates the adequate use of indicators for different purposes and target groups. First- and second-level indicators are helpful for describing productivity of a company on an aggregated level. However, responsibilities and appropriate measures are difficult to determine, because of the involvement of different company departments. Such indicators are not suited for the scope of this study, as it would complicate a transparent impact evaluation of specific freight rail processes on productivity. The relevance of freight rail processes on productivity should therefore be evaluated by means of the underlying indicators representing the effectiveness, efficiency, unit costs, and earning power of freight railways.

**Figure B.4: Hierarchical structure of identified generic indicators**

## B.2. Proposed Indicators

### B.2.1. Input and Output Factors in Rail Freight

Scientific studies dealing with productivity in freight rail use a great variety of input and output factors (e.g. HILMOLA (2007), LAN AND LIN (2006), OUM AND WATERS (1999), WIEGMANS ET AL. (2007), YU AND LIN (2008)). However, the number and types of applied factors vary significantly among the surveyed studies. Furthermore, most of the existing studies on freight rail productivity focus on quantitative analyses using complex mathematical methods. The necessity of available data thus inevitably influences the selection of input and output factors. There are only few studies such as CHRISTOPH ET AL. (2006), which propose specific input and output factors from a company's point of view. The granted access to internal productivity indicators at SBB Cargo has therefore been an important additional source to discuss the relevance of certain input and output factors.

The selection of possible input factors is done in consideration of what resources freight railways directly need for running a train. Main line locomotives, freight wagons and train drivers are evidently needed to accomplish this task. Additionally, train paths are required to access and use the rail infrastructure. For freight rail companies with a significant single wagonload service, the numbers of shunting locomotives and shunters have to be considered as well. This leads to a total of five specific input factors. These input factors can also be expressed financially by measuring their costs. Typical examples are salaries, investments in rolling stock, maintenances, or train-path cancellation fees.

The actual output of freight railways is shipping freight-wagons from A to B. The most aggregated figure for describing this actual output is gross tons-km. It reflects both distance and weight of transports with no regards of service types or involved resources. However, the actual output of many input resources, such as train drivers, is not weight-dependant. In this case, the measurement of train-km or wagon-km as actual output is more accurate. Some inputs are not even distance-dependant. This typically applies for

shunters and shunting locomotives. Their task is to collect and deliver freight-wagons on the last mile. The counting of shipped freight wagons is already sufficient in this case.

In analogy to actual output, the consumed output from customers of rail freight services is most comprehensively measured by net tons-km. It reflects the performance of freight railways by means of both distance and weight but rightly ignores (unpaid) empty freight wagons shipments. In practice however, block train and single wagonload services are actually not billed on the effective weight. The price per shipped train or wagon usually remains constant for a customer, as an average weight has been agreed on during price negotiations. Hence, consumed output can also be measured by means of train-km for block train services and loaded wagon-km for single wagonload services. At last, the itinerary of freight wagons in single wagonload services is dependant on the network approach and does usually not reflect the shortest distance from sender to receiver. To exclude this influence, the number of delivered loaded freight wagons can be used for expressing the consumed output in single wagonload services. Consumed output can eventually also be expressed in financial terms. With regards to freight railways, this is most accurately done with measuring transport revenue.

Table B.2 summarises the results by listing the proposed specific input and output elements for describing rail freight productivity.

**Table B.2: Specific input and output elements for describing rail freight productivity**

input	costs <sup>1</sup>	actual output	consumed output	revenue
main line locomotives	main line locomotive costs	gross tons-km	net tons-km	transport revenue
freight wagons	freight wagon costs	train-km	train-km <sup>2</sup>	
train drivers	train driver costs	freight wagon-km	loaded freight wagon-km <sup>3</sup>	
shunting locomotives	shunting locomotive costs	no. of shipped freight wagons	no. of loaded freight wagons <sup>3</sup>	
shunters	shunters costs			
ordered train path-km	train path costs			

<sup>1</sup> kilometre-independent components of costs only

<sup>2</sup> for block train services only

<sup>3</sup> for single wagonload services only

### B.2.2. Efficiency indicators for Freight Railways

Efficiency has been defined as ratio of actual outputs to actual inputs. In order to create useful ratios, the actual output must reflect the capabilities of responsible planning units to improve the efficiency of a specific input factor.

In case of train drivers and main line locomotives, production planning can improve the average train-km performance by minimizing idle times between productive duties, for instance. However, it can generally not control the weight of trains. Efficiency of main line locomotives and train drivers should therefore be measured by means of train-km rather than gross tons-km. The same applies for freight wagons, whose efficiency is most accurately measured by means of freight wagon-km.

The situation is different when measuring the efficiency of shunters and shunting locomotives. They are responsible for the collection and delivery of freight wagons on the last mile of transports. Maximizing the number of delivered or collected wagons for each shunter or shunting locomotive is therefore an important efficiency goal. In turn, shipment weight and transport distances are irrelevant elements. The number of shipped freight wagons is therefore taken as basis for measuring the efficiency of shunting locomotives and shunters.

Chapter B.2.1 lists ordered train path-km as another possible input factor. In practice however, measuring the efficiency of this input is irrelevant as ordered train path-km are actually equal to effected train-km. This is because ordered train paths are cancelled as soon as it is certain that there will be no trains using them. Additionally, freight railways book train paths within a range of one year until the very day of transport. These circumstances make it impossible to measure the amount of ordered train path-km earlier than on the very last day, where ordered train path-km become equal with effected train-km.

Figure B.5 summarizes the proposed effectiveness indicators for freight railways as a result of this discussion.

**Figure B.5: Proposed efficiency indicators for freight railways**

	$\frac{\text{train-km}}{\text{train driver}}$	$\frac{\text{wagon-km}}{\text{freight wagon}}$
$\frac{\text{train-km}}{\text{main line locomotive}}$	$\frac{\text{no. of shipped wagons}}{\text{shunting locomotive}}$	$\frac{\text{no. of shipped wagons}}{\text{shunter}}$

### B.2.3. Effectiveness indicators for freight railways

Effectiveness has been defined as ratio of consumed outputs to actual outputs. Its measurement depends on both the freight rail service and aggregation level. An aggregated measurement of effectiveness for all freight rail services is only possible by using net tons-km. This is because the net-weight and distance are the only common indicators for block train and single wagonload services. The measurement of effectiveness on the basis of net tons-km is useful for the external communication of freight railways, as it allows giving an overall information about the performance. For

intra-company purposes though, the measurement of net tons-km is not accurate enough. This is because customers are responsible for the actual utilisation rate of their ordered block trains or single wagons. Consequently, a low net weight of a train or freight wagon does not automatically affect the effectiveness of freight railways. Furthermore, the expected average net-weight of trains or freight wagons is actually of minor relevance for freight railways unless traction force has to be increased with a second locomotive. This is primarily relevant for (international) trains crossing the alps but rather uncommon for domestic trains in Switzerland, which are in focus of this study.

In fact, the effectiveness of block train services is close to 100%. No block train is running without an underlying customer order. Hence, the actual output for block trains automatically corresponds with the consumed output. The measurement of effectiveness for block train services is therefore irrelevant.

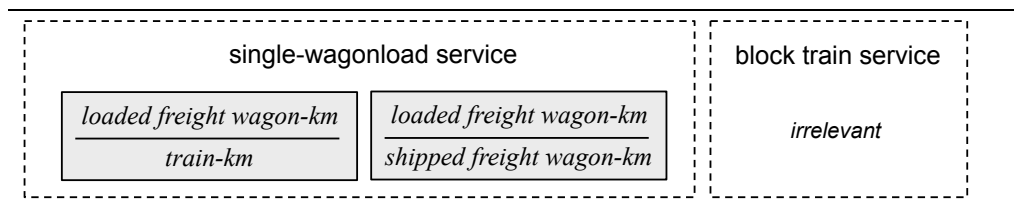
Effectiveness is an important issue in single wagonload services however, where a regular train schedule is offered to customers. The consumed output can be either measured by means of loaded freight wagon-km or the total number of loaded freight wagons. Only three indicators are reasonable in practice. Table B.3 lists these indicators and evaluates their relevance and interdependencies on the basis of some common effectiveness measures.

**Table B.3: Discussion of effectiveness indicators in single wagonload service**

<i>Measure</i>	<b>loaded freight wagon-km / freight wagon-km (1)</b>	<b>loaded freight wagon-km / train-km (2)</b>	<b>no. of loaded freight wagons / no. of shipped freight wagons (3)</b>
<i>Increase immediate reloading of freight wagons</i>	impact	no impact	impact
<i>Shorten distance of empty wagon transports</i>	impact	no impact	no impact
<i>Combine scheduled single-wagonload trains</i>	no impact	impact	no impact
<i>Increase sales</i>	no impact	impact	no impact

Table B.3 clearly shows the complementing character of indicators 1 and 2. The use of indicator 3 would provide no added value, as it represents a subset of indicator 1.

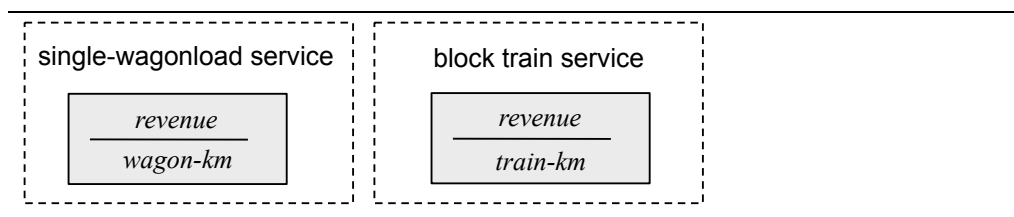
Figure B.6 summarizes the proposed effectiveness indicators for freight railways as a result of this discussion.

**Figure B.6: Proposed effectiveness indicators for freight railways**

### B.2.4. Earning Power Indicators for Freight Railways

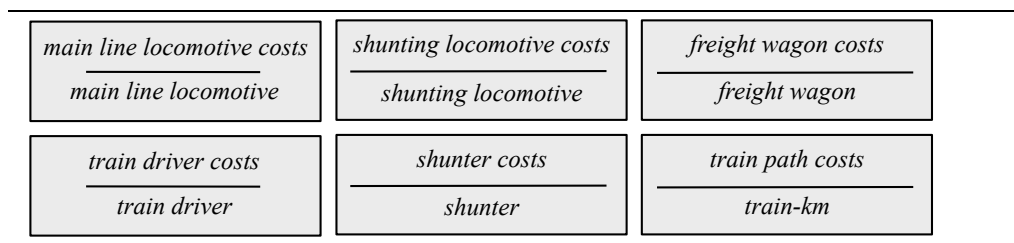
Earning power has been defined as ratio of revenue and consumed output. An aggregated measurement of earning power is only possible by using net tons-km as consumed output. This is useful for the external communication of freight railways but should be avoided for intra-company purposes (compare analogue discussion in chapter B.2.3.).

Hence, the most accurate indicator for describing the earning power for block train services is revenue per train-km and revenue per wagon-km for single wagonload services.

**Figure B.7: Proposed earning power indicators for freight railways**

### B.2.5. Unit Cost Indicators for Freight Railways

Unit costs have been defined as ratio of an input and its related costs. Hence, specific unit costs for freight railways can be elaborated by combining the identified input factors with their corresponding cost factors. This leads to six unit cost ratios, which are shown in Figure B.8.

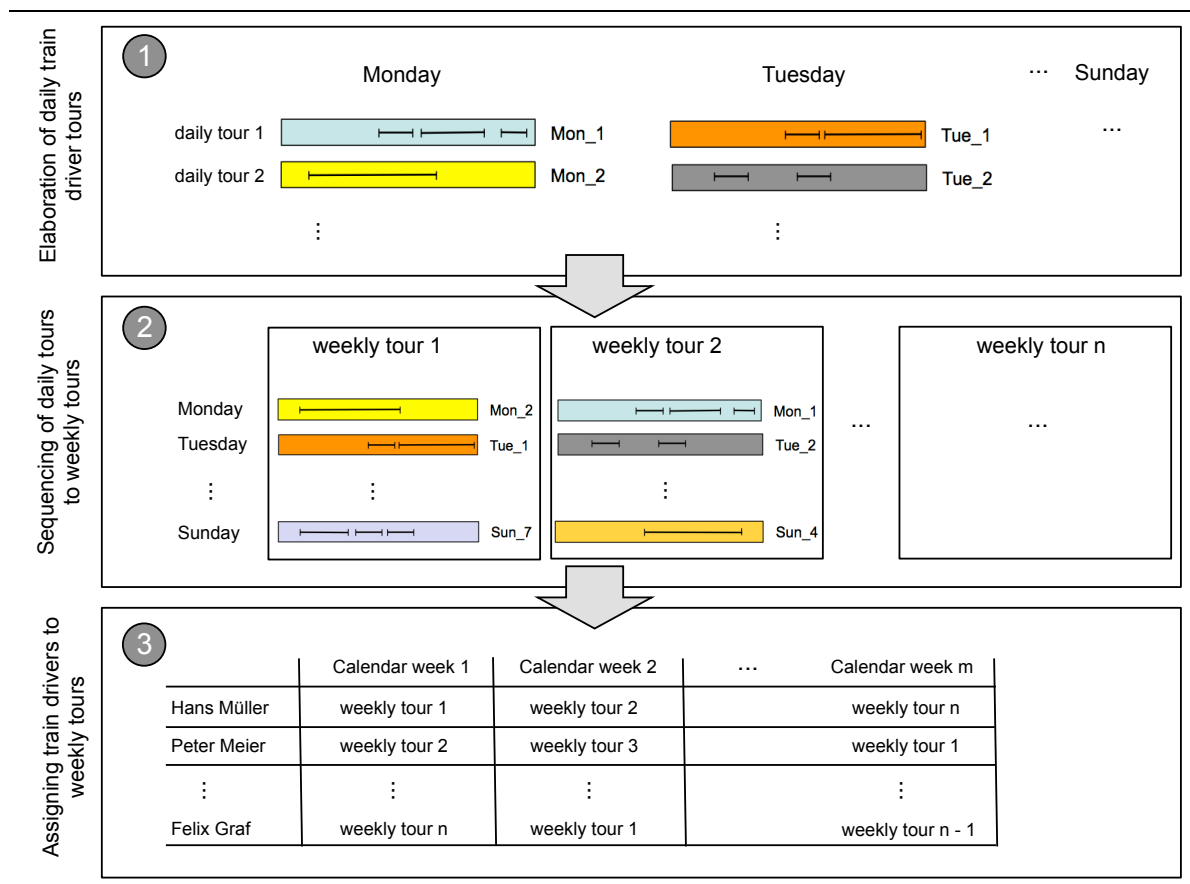
**Figure B.8: Proposed unit cost indicators for freight railways**



## Appendix C – Elaboration of annual roster for train drivers

Figure C.1 shows the simplified process for elaborating annual rosters for train drivers. Based on the planned transport services, train driver tours are elaborated for each day (1). These tours already include time windows for potential short-term block train services. In a second step, these daily tours are sequenced to weekly tours, considering legal constraints (2). Day offs are integral part of these weekly tours. Finally, the weekly tours are brought in an operational reasonable and legally compatible order and specific train drivers are assigned to (3).

**Figure C.1: Process of elaborating annual roster for train drivers**



## Appendix D – Analysis of selected transport sectors

### *Definitions*

**Transport volumes** are calculated on the basis of block trains (intermodal transports, mineral oil sector, gravel sector, and tunnel excavation transports) or freight wagons (steel sector).

A specific transport relation is classified as **frequently used**, if transport volumes occur at more than 80% of all calendar weeks in a three-month period.

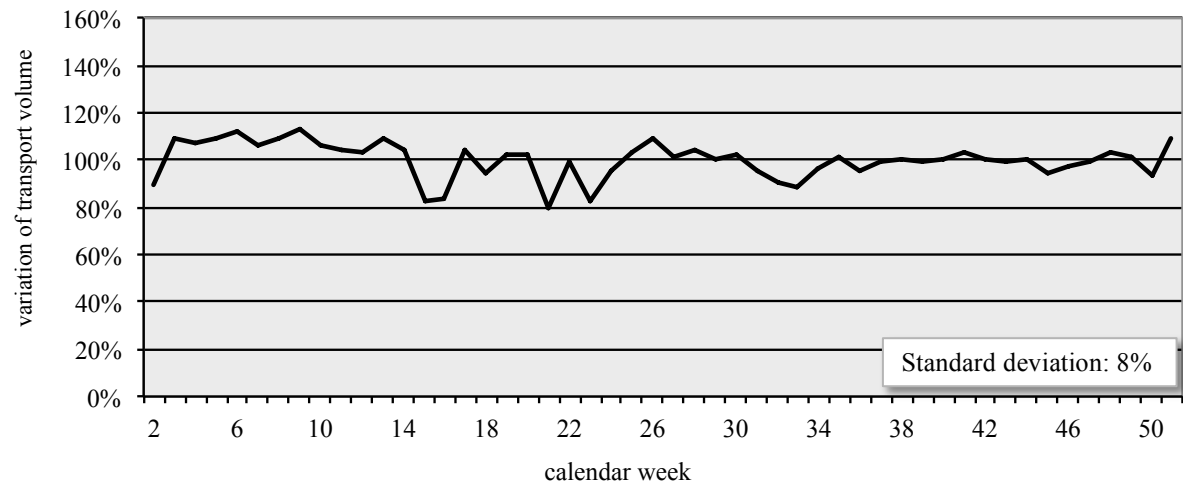
A specific transport relation is classified as **occasionally used**, if transport volumes occur between 20% - 80% of all calendar weeks in a three-month period.

A specific transport relation is classified as **rarely used**, if transport volumes occur at less than 20% of all calendar weeks in a three-month period.

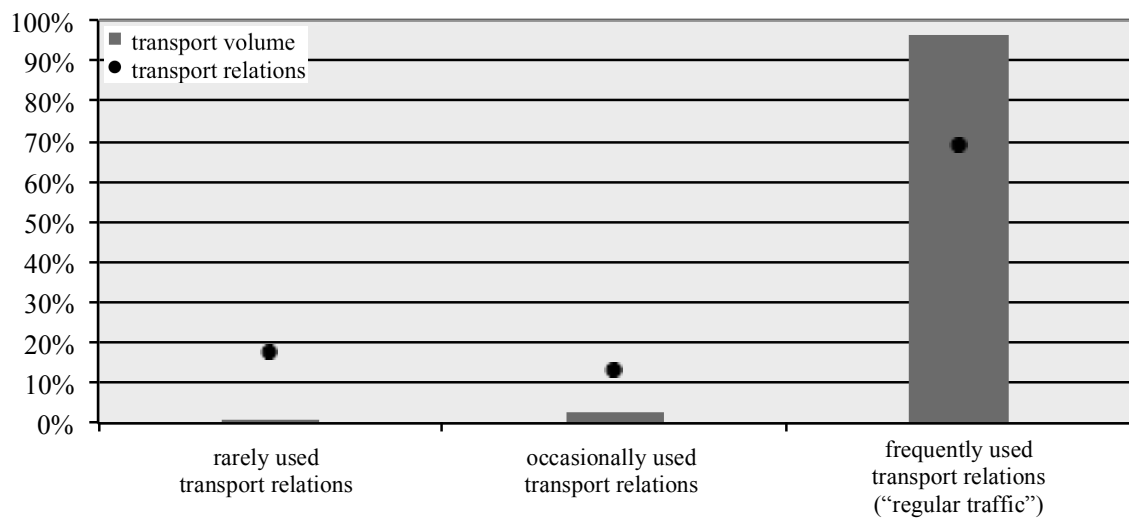
Transport volumes on frequently used transport relations are defined as **regular traffic**.

### *Data:*

The quantitative analyses are based on data provided by SBB Cargo. They comprise transport volumes of analysed commodities/sectors in Switzerland during 2009 without transit.

**Figure D.1: Variation of weekly transport volumes for intermodal transports**

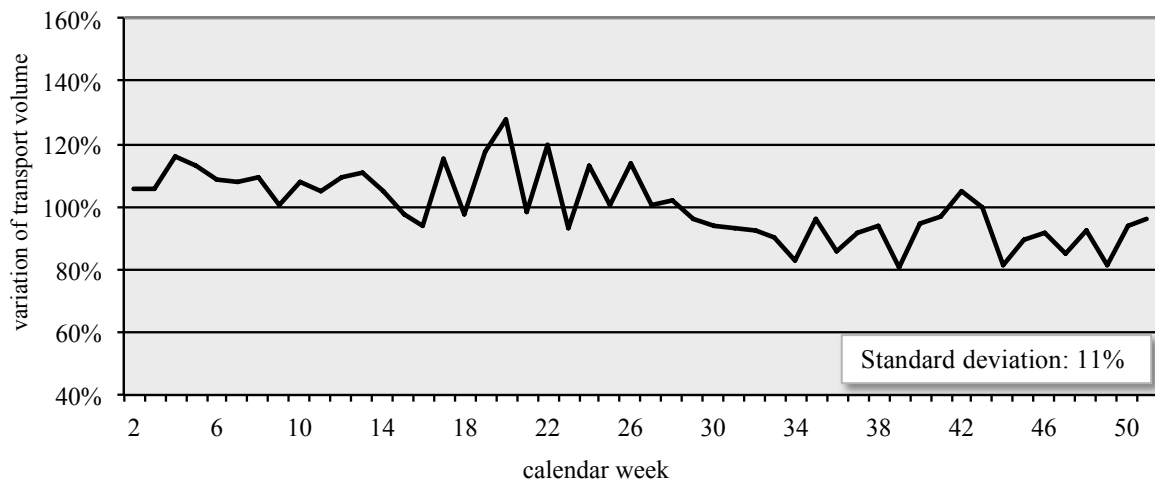
Data: SBB Cargo (intermodal trains in Switzerland during 2009 without transit)

**Figure D.2: Share of regular traffic at intermodal transports**

Data: SBB Cargo (intermodal trains in Switzerland during 2009 without transit)

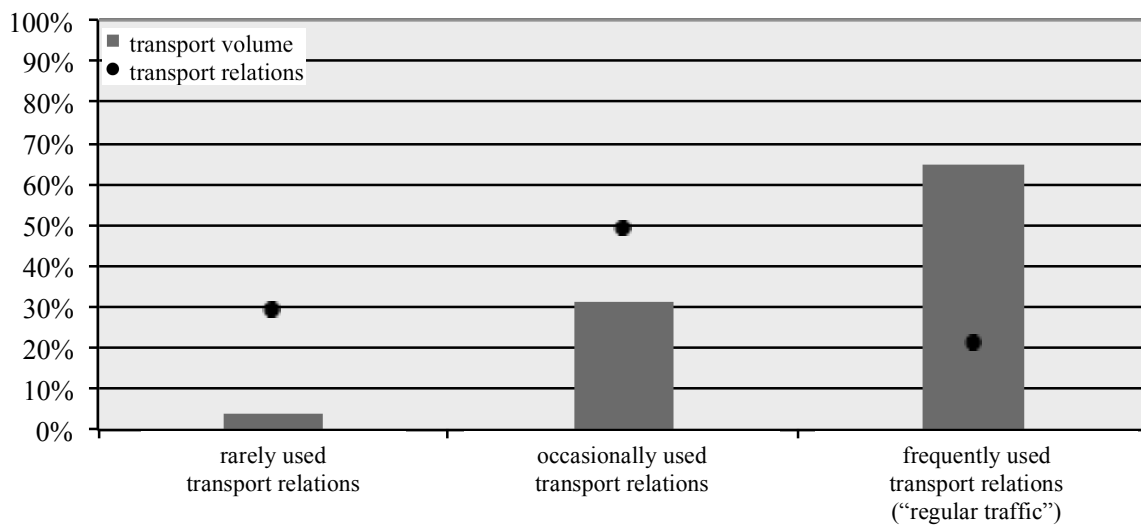
97% of transport volume operated as regular traffic  
69% of transport relations operated as regular traffic

**Figure D.3: Variation of weekly transport volumes in the mineral oil sector**



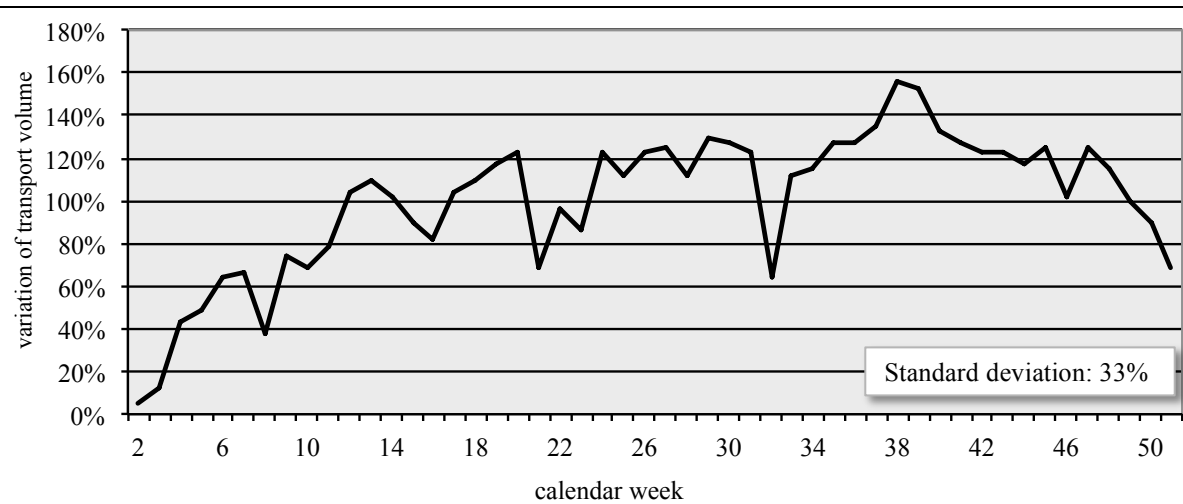
Data: SBB Cargo (mineral oil trains in Switzerland during 2009 without transit)

**Figure D.4: Share of regular traffic in the mineral oil sector**

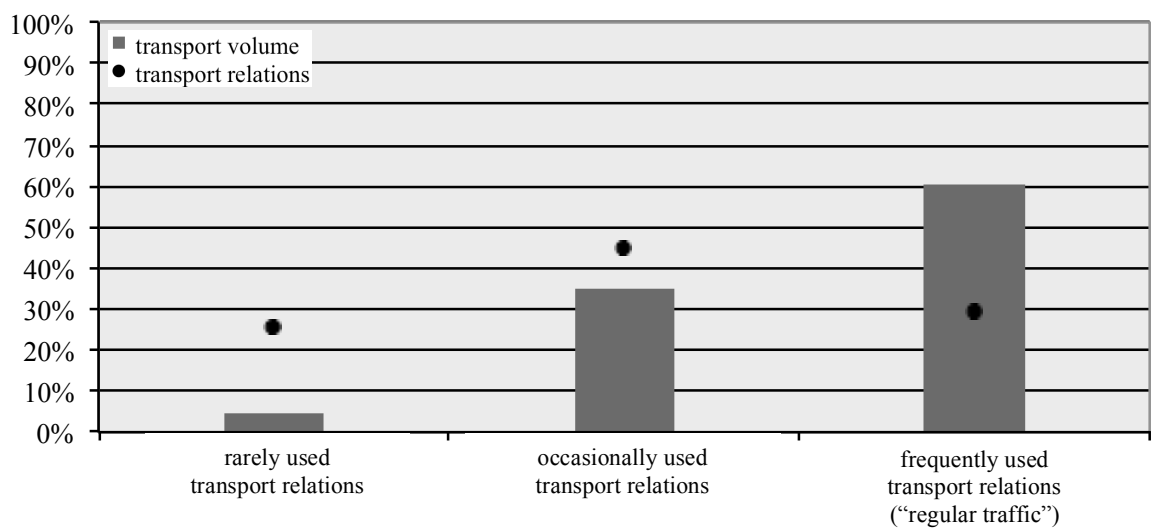


Data: SBB Cargo (mineral oil trains in Switzerland during 2009 without transit)

65% of transport volume operated as regular traffic  
 21% of transport relations operated as regular traffic

**Figure D.5: Variation of weekly transport volumes in the gravel sector**

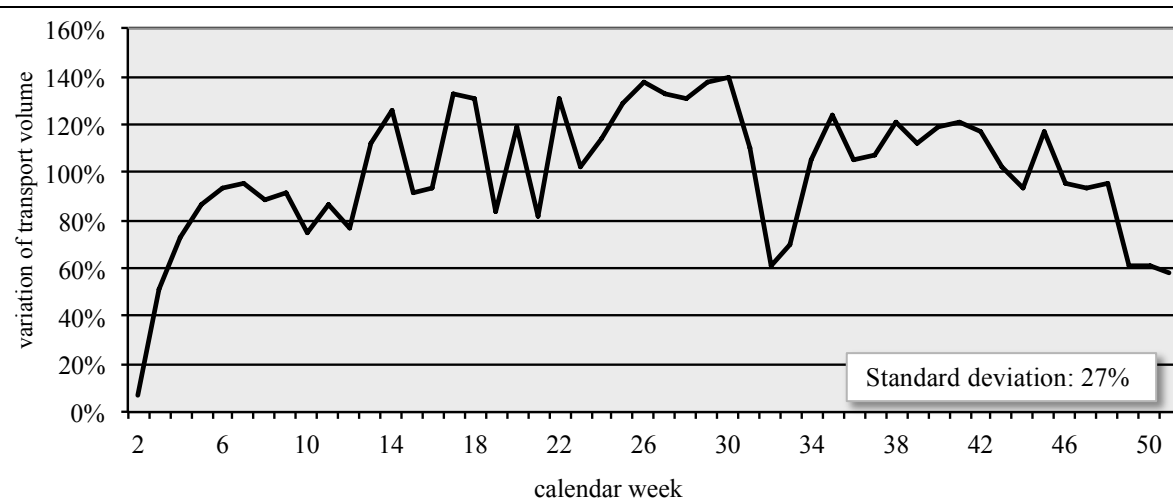
Data: SBB Cargo (gravel trains in Switzerland during 2009 without transit)

**Figure D.6: Share of regular traffic in the gravel sector**

Data: SBB Cargo (gravel trains in Switzerland during 2009 without transit)

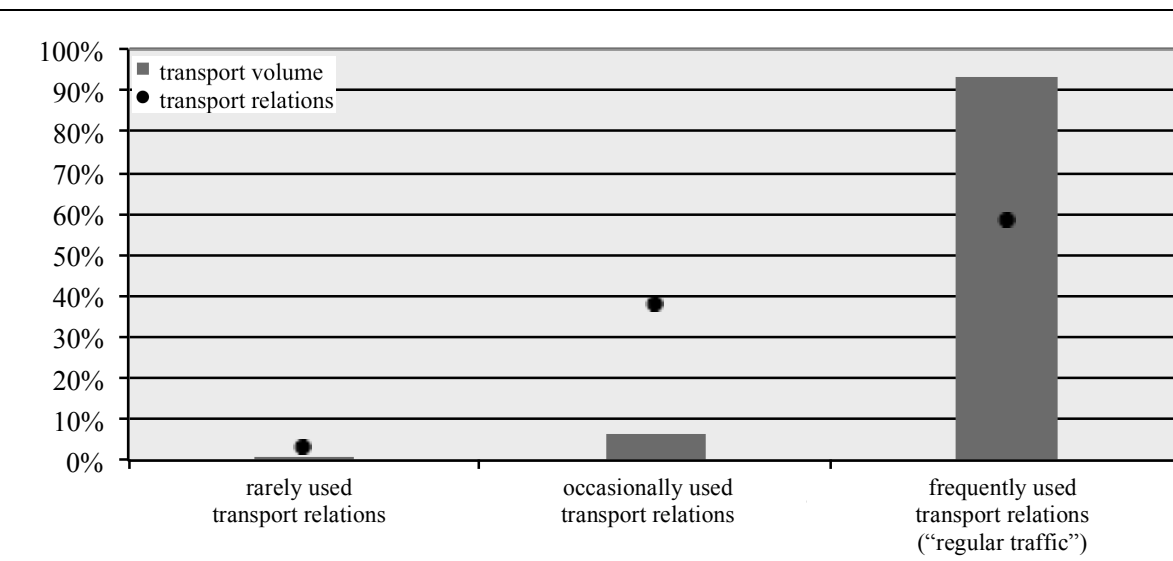
61% of transport volume operated as regular traffic  
29% of transport relations operated as regular traffic

**Figure D.7: Variation of weekly transport volumes for tunnel excavation transports**



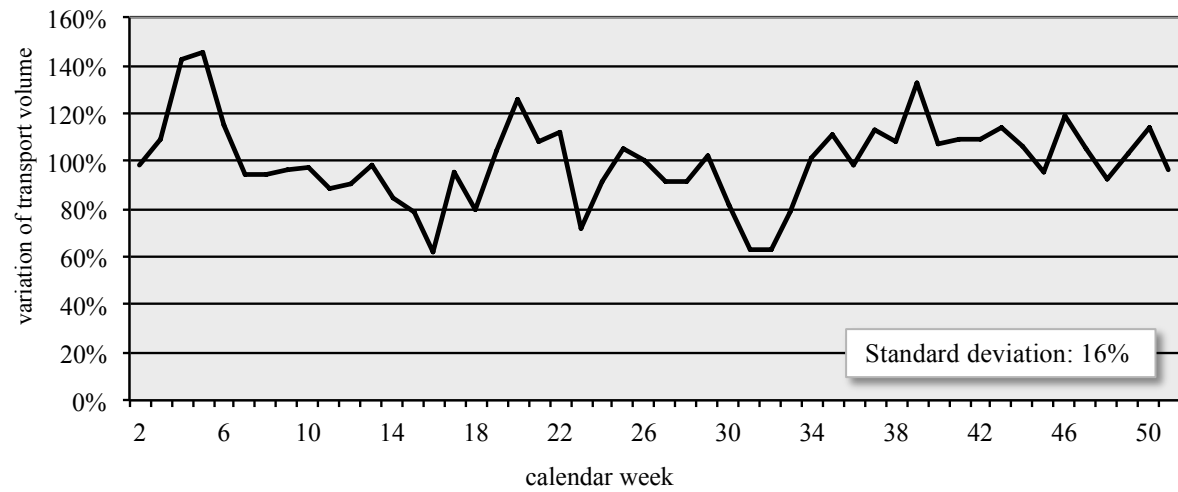
Data: SBB Cargo (trains shipping tunnel excavation in Switzerland during 2009 without transit)

**Figure D.8: Share of regular traffic at tunnel excavation transports**

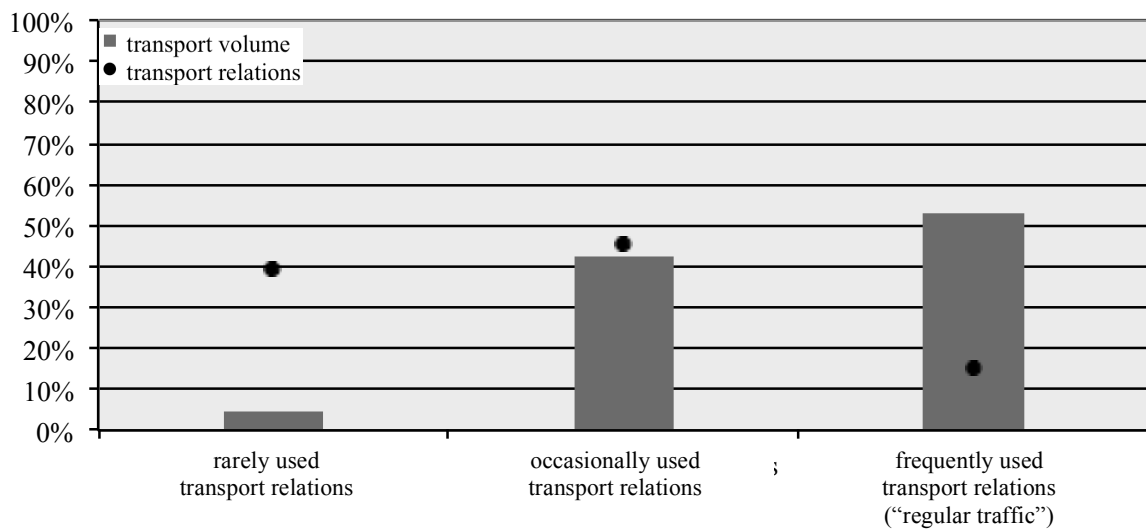


Data: SBB Cargo (trains shipping tunnel excavations in Switzerland during 2009 without transit)

94% of transport volume operated as regular traffic  
59% of transport relations operated as regular traffic

**Figure D.9: Variation of weekly transport volumes in the steel sector**

Data: SBB Cargo (wagons shipping steel products and steel scrap in Switzerland during 2009 without transit; no block trains)

**Figure D.10: Share of regular traffic in the steel sector**

Data: SBB Cargo (wagons shipping metallurgical products and secondary raw material (steel scrap) in Switzerland during 2009 without transit; no block trains)

53% of transport volume operated as regular traffic  
15% of transport relations operated as regular traffic

## Appendix E – Interview guideline

### 1. Allgemeine Fragen zur Unternehmung

- 1.1. Tätigkeitsbereich der Unternehmung
- 1.2. Charakteristik der Start-/Zieldestinationen der Züge
- 1.3. Art der Lieferanten und Abnehmer des Transportgutes

### 2. Transportplanung

#### *Grundlagen*

- 2.1. Auf welchen Grundlagen basiert die Transportplanung (Kundenbestellungen, Erfahrung, ...)?
- 2.2. Welchen Zeithorizont umfasst die Transportplanung? Was ist der Grund dafür?
- 2.3. Von wem stammen die notwendigen Informationen? In welcher Form/Detaillierung?
- 2.4. Wann sind sie erhältlich und in welcher Qualität?
- 2.5. Was sind die zentralen Einflussfaktoren auf die Planungsgrundlagen? Können diese beeinflusst werden (z.B. Zeitpunkt der Bestellungen der Kunden)?
- 2.6. Wie oft werden die Grundlagen für die Transportplanung aktualisiert? Wer ist dafür verantwortlich?

#### *Transportplanerstellung*

- 2.7. Welche Aufgaben umfasst die Transportplanerstellung (Transportmittelwahl, Bestimmung von Frachteinheiten, ...)?
- 2.8. Wer ist involviert?
- 2.9. Wie gross ist der zeitliche Aufwand?
- 2.10. Wie stabil wird der Transportplan eingeschätzt? Was sind ggf die Gründe für einen instabilen Transportplan?

### 3. Übermittlung Transportbedarf

#### *Prognose*

- 3.1. Werden Prognosen an Güterbahnen (z.B. SBB Cargo) weitergeleitet?
  - 3.1.1. Wenn ja,
    - warum?
    - in welcher Form und Häufigkeit?
    - wie gross ist der Zusatzaufwand?
  - 3.1.2. Wenn nein, warum nicht?

#### *Bestellung*

- 3.2. Wer übermittelt die Bestellungen an die Güterbahn (z.B. SBB Cargo)?
- 3.3. Wie werden die Bestellfristen der Güterbahnen (z.B. SBB Cargo) beurteilt?

### 4. Änderungsmanagement

- 4.1. Welche Arten von Änderungen im Transportplan gibt es?
- 4.2. Was sind die Ursachen?
- 4.3. Wie wird intern damit umgegangen?
- 4.4. Bei Lieferung von Prognosen: Wann werden Änderungen an die Güterbahnen (z.B. SBB Cargo) übermittelt (sofort, erst bei definitiver Bestellung, ...)?



---

## Appendix F – Basic Definitions

### *Shipper:*

UN/ECE 2001 defines *shipper* as a person or company who puts goods in the care of others (freight forwarder, carrier) to be delivered to a consignee (also referred to as “sender” or “consignor”). This study uses the term *shipper* in a wider sense to describe the actor in transport logistics, which is responsible for the organisation of the shipment, be it in the position of the sender or the receiver. Being responsible for the organisation of shipments includes, inter alia, that a shipper maintains the contractual relationship with freight forwarders/carriers and initiates actual shipments.

### *Shipment:*

The term *shipment* describes goods transported under the terms of a single bill of lading, irrespective of the quantity or number of containers, packages, or pieces (also referred to as “consignment”). In the specific case of rail freight, shipments lot sizes are typically in the range of single wagons, group of wagons or block trains.

### *Carrier:*

A *carrier* is a person or company responsible for the carriage of goods, either directly or using a third party [UN/ECE 2001]. In this study, the term *carrier* is typically referred to freight railways.

## Appendix G – Curriculum Vitae

### Stephan Moll

born on February 5, 1979 in Zurich, Switzerland

citizen of Dulliken (Solothurn)

#### Practical Experience

since June 2012	Head of Production Planning at BLS Cargo, Bern, Switzerland
June 2008 – May 2012	Research Assistant at ETH Zurich, Institute for Transport Planning and Systems, Chair for Transportation Systems
Aug. 2007 – May 2008	Business Analyst Planning and Controlling at SBB Cargo, Basel, Switzerland
Aug. 2005 – July 2007	Management Trainee at SBB Cargo, Basel, Switzerland
Aug. 2006 – Jan. 2007	Internship at GEFCO, Paris, France (carried out as part of the Management Trainee Program of SBB Cargo)
Sep. 2004 – Dec. 2004	Internship at AUDI AG, Neckarsulm, Germany

#### Higher Education

Oct. 2002 – July 2005	Study of Industrial Management and Manufacturing at ETH Zurich with focus on logistics management and metal forming technologies
Oct. 2000 – Sep. 2002	Study of Mechanical and Process Engineering at ETH Zurich
Jan. 2000	Matura at MNG Rämibühl, Zurich

# Bibliography

- ARNOLD ET AL. (2008) D. Arnold, H. Isermann, A. Kuhn, H. Tempelmeier, and K. Furmans; Handbuch Logistik. Springer Verlag. Berlin, 2008.
- AWEL (2011) Amt für Abfall, Wasser, Energie und Luft; URL: [http://www.awel.zh.ch/internet/audirektion/awel/de/abfall\\_rohstoffe\\_altlasten/rohstoffe/kies\\_und\\_lehm.htm](http://www.awel.zh.ch/internet/audirektion/awel/de/abfall_rohstoffe_altlasten/rohstoffe/kies_und_lehm.htm). Accessed 20.09.2011.
- BALZERT (2008) H. Balzert; Java 5: Der Einstieg in die Programmierung: Strukturiert und Prozedural programmieren. W3I GmbH. Herdecke, 2008.
- BARNES (2008) D. Barnes; Operations Management: An International Perspective. Thomson Learning. London, 2008.
- BEA ET AL. (2001) F. X. Bea, E. Dichtl, and M. Schweitzer; Allgemeine Betriebswirtschaftslehre – Band 2: Führung. Lucius & Lucius Verlag. Stuttgart, 2001.
- BENDUL (2010) J. Bendul; Kapazitätsmanagement. In: W. Stölzle and H.P. Fagagnini (eds.); Güterverkehr kompakt. Oldenbourg Verlag. München, 2010.
- BAYER (2005) M. Bayer; Höchste Eisenbahn fürs Wagenmanagement. Computerwoche. 46 (2005).
- BERNDT (2001) T. Berndt; Eisenbahngüterverkehr. Teubner Verlag. Stuttgart, 2001.
- BEYGANG (2008) K. Beygang; Modelle und Algorithmen für die Leerwagendisposition im Schienengüterverkehr. Diplomarbeit Technische Universität Kaiserslautern. Kaiserslautern, 2008.
- BOOCH ET AL. (2006) G. Booch, J. Rumbaugh, and I. Jacobson; Das UML Benutzerhandbuch. Addison-Wesley Verlag. München, 2006.
- BOPP ET AL. (1996) G. Bopp, R. Brimhall, B. Gallaher, P. Johnson, M. Kuntamukkula, and W. Lyons; General Engineering and Science. In: W. Lyons (ed.); Standard handbook of petroleum & natural gas engineering. Gulf Publishing Company. Houston, 1996.

- CAPRARA ET AL. (2006) A. Caprara, L. Kroon, M. Monaci, M. Peeters, and P. Toth; Passenger Railway Optimisation. Publication of EC research project ARRIVAL. URL: <http://arrival.cti.gr/index.php/Documents/0035>. Accessed 25.05.2011.
- CHAN AND ZHANG (2011) F. Chan and T. Zhang; The impact of Collaborative Transportation Management on supply chain performance: A simulation approach. *Expert Systems with Applications*. 38 (2011), No. 3, pp. 2319-2329.
- CHEREMISINOFF (2003) N. Cheremisinoff; *Handbook of Solid Waste Management and Waste Minimization Technologies*. Butterworth-Heinemann. Burlington, 2003.
- CHRISTOPH ET AL. (2006) J. Christoph, T. Kühne, and Ch. Schneider; Unternehmensführung im Schienengüterverkehr mit Kennzahlen. *Internationales Verkehrswesen*. 4 (2006), pp. 151-155.
- CLAUSEN AND KOCHSIEK (2008) U. Clausen and J. Kochsiek; Einbindung des Verkehrsträgers Schiene in die Logistikketten. *EI-Eisenbahningenieur*. June 2008, pp. 48-51.
- CLAUSEN AND BAUDACH (2008) U. Clausen and J. Baudach; Crew Scheduling as one Part of Optimal Resource Allocation in Railway Freight Transportation. In: D.C. Mattfeld, H.-O. Günther, L. Suhl, and S. Voss (eds.); *Informations- und Kommunikationssysteme in Supply Chain Management, Logistik und Transport*. DS&OR Lab. Universität Paderborn, 2008.
- COLE (2006) A. Cole; The Influence Matrix Methodology: a technical report. Landcare Research. URL: [http://icm.landcareresearch.co.nz/knowledgebase/publications/public/iMatrix\\_Tech\\_Report.pdf](http://icm.landcareresearch.co.nz/knowledgebase/publications/public/iMatrix_Tech_Report.pdf). Accessed: 16.03.2012
- DE JORGE-MORENO (1999) J. de Jorge-Moreno and L.I. Garcia-Cebrian; Measuring of production efficiency in the European railways. *European Business Review*. 99 (1999), No. 5, pp. 332 - 344.
- DENZIN AND LINCOLN (1994) N.K. Denzin and Y.S. Lincoln; *Handbook of qualitative research*. Sage Publications. Thousand Oaks, 1994.
- DICKERSBACH (2007) J. Dickersbach; *Service Parts Planning with mySAP SCM - processes, structures, and functions*. Springer Verlag. Berlin, 2007.

- DOMSCHKE AND SCHOLL (2005) W. Domschke and A. Scholl; Grundlagen der Betriebswirtschaftslehre. Springer Verlag. Berlin, 2005.
- DRUCKER (1980) P.F. Drucker; Management: Tasks, Responsibilities, Practices. New York u.a., 1980.
- DUDEK (2009) G. Dudek; Collaborative Planning in Supply Chains. Springer Verlag. Berlin, 2009.
- ELBERT AND GOMM (2003) R. Elbert and M. Gomm; Zukunftsforschung Güterverkehr: Eine Studie über die Auswirkungen sich ändernder Rahmenbedingungen im Güterverkehr auf Unternehmen. In: Chr. Pfohl (ed.); Güterverkehr – Eine Integrationsaufgabe für die Logistik. Erich Schmidt Verlag. Berlin, 2003.
- ESPER AND WILLIAMS (2003) T. Esper and L. Williams; The Value of Collaborative Transportation Management (CTM): Its Relationship to CPFR and Information Technology. Transportation Journal. 42 (2003), No. 4, pp. 55 - 65.
- EV (2009) Erdöl-Vereinigung; Erdölbilanz der Schweiz. Jahresbericht 2009.
- EV (2010) Erdöl-Vereinigung; Erdöl und Produkte: Herkunft und Transport in die Schweiz. inside. 2/2010.
- EZV (2010) Eidgenössische Zollverwaltung; D.9 Verwaltungsvorschriften Mineralölsteuer. URL: [www.ezv.admin.ch/dokumentation/01113/index.html?lang=de](http://www.ezv.admin.ch/dokumentation/01113/index.html?lang=de). Accessed 14.04.2011.
- FENG ET AL. (2005) T. C.-M. Feng, C.-Y. Yuan, and Y.-C. Lin; The System Framework for Evaluating the Effect of Collaborative Transportation Management on Supply Chains. Journal of the Eastern Asia Society for Transportation Studies. 6 (2005), pp. 2837 - 2851.
- FLEISCHMANN (2008) B. Fleischmann; Distribution and Transport Planning. In: H. Stadtler and Ch. Kilger (eds.); Supply Chain Management and Advanced Planning. Springer Verlag. Berlin, 2008.
- FLEISCHMANN ET AL. (2008) B. Fleischmann, H. Meyr, and M. Wagner; Advanced Planning. In: H. Stadtler and Ch. Kilger (eds.); Supply Chain Management and Advanced Planning. Springer Verlag. Berlin, 2008.

- FRIES (2010) N. Fries; Market Potential and Value of Sustainable Freight Transport Chains. Scientific Series of the Institute for Transport Planning and Systems, 148, ETH Zürich. Zürich, 2010.
- FSKB (2011) Fachverband der Schweizerischen Kies- und Betonindustrie (FSKB). URL: <http://www.fskb.ch>. Accessed 20.09.2011.
- GILLIAM (2008) D. Gilliam; Lärmreduzierungsstrategien aus der Sicht eines privaten Güterwagenhalters. Presentation at Fachtagung Güterverkehr, VDV-Jahrestagung. Nürnberg, 2008.
- GLÄSER AND LAUDEL (2009) J. Gläser and G. Laudel; Experteninterviews und qualitative Inhaltsanalyse. Verlag für Sozialwissenschaften. Wiesbaden, 2009.
- GOMEZ AND PROBST (1995) P. Gomez and G. Probst; Die Praxis des ganzheitlichen Problemlösens : vernetzt denken, unternehmerisch handeln, persönlich überzeugen. Haupt Verlag. Bern, 1995.
- GORDEN AND HAYWARD (1968) T.J. Gordon and H. Hayward; Initial experiments with the cross impact matrix method of forecasting. Futures. 1(1968), pp. 100-116
- HAUBER (2002) R. Hauber; Performance Measurement in der Forschung und Entwicklung. DUV Verlag, Wiesbaden, 2002.
- HILMOLA (2007) O.P. Hilmola; European railway freight transportation and adaptation to demand decline – Efficiency and partial productivity analysis from period of 1980-2003. International Journal of Productivity and Performance Measurement. 56 (2007), No. 3, pp. 205-225.
- HOFER (1984) C. W. Hofer and D. Schendel; Strategy Formulation: Analytical Concepts. St. Paul, 1984.
- INTERTRANS (2010) InTerTrans; Integrierte Produktions- und Transportplanung in der Automobilindustrie zur Steigerung der ökologischen Effizienz. URL: [www.inter-trans.eu](http://www.inter-trans.eu). Accessed 04.02.2011.
- JUNG (2006) H. Jung; Allgemeine Betriebswirtschaftslehre. Oldenbourg Verlag. München, 2006.
- KING ET AL. (1994) G. King, R. Keohane, and S. Verba; Designing Social Inquiry. Princeton University Press. Princeton, 1994.

- KILGER ET AL. (2008) Ch. Kilger, B. Reuter, and H. Stadtler; Collaborative Planning. In: H. Stadtler and Ch. Kilger (eds.); Supply Chain Management and Advanced Planning. Springer Verlag. Berlin, 2008.
- KORELL AND SCHASCHKE (2007) M. Korell and M. Schaschke; Customer Knowledge Management – Durch systematische Integration von Kundenwissen die Innovationskraft steigern. Fraunhofer IRB Verlag. Stuttgart, 2007.
- KORNDÖRFER (2003) W. Korndörfer; Allgemeine Betriebswirtschaftslehre. Gabler Verlag. Wiesbaden, 2006.
- KOSANKE (2005) K. Kosanke; Standardisation in Enterprise Inter- and Intraorganizational Integration. International Journal of IT Standards and Standardization Research. 3 (2005), Issue 2, pp 42-50.
- LAN AND LIN (2006) L.W. Lan and E.T.J. Lin; Performance Measurement for Railway Transport: Stochastic Distance Functions with Inefficiency and Ineffectiveness Effects. Journal of Transport Economics and Policy. 40 (2006), pp. 383-408.
- LAUTENSCHLÄGER ET AL. (2005) K.-H. Lautenschläger, W. Schröter, and A. Wanninger; Taschenbuch der Chemie. Harri Deutsch Verlag. Frankfurt am Main, 2005.
- MEYER AND STADTLER (2008) H. Meyer and H. Stadtler; Types of Supply Chains. In: H. Stadtler and Ch. Kilger (eds.); Supply Chain Management and Advanced Planning. Springer Verlag. Berlin, 2008.
- MOLL AND WEIDMANN (2011) S. Moll and U. Weidmann; Partial Productivity Measurement in Rail Freight Transport. european railway review. 17 (2011), No. 2, pp. 28-32.
- NAGEL (2008) C. Nagel; The integration of rail transport into freight transport logistics chains of logistics service providers. TU Berlin. Berlin, 2008.
- NÜTTGENS (2008) M. Nüttgens; EPK. In: K. Kurbel, J. Becker, N. Gronau, E. Sinz, and L. Suhl (eds.); Enzyklopädie der Wirtschaftsinformatik – Online Lexikon. Oldenbourg Wissenschaftsverlag.
- NYSETVOLD (2006) A. Nysetvold; Assessing Business Process Modeling Languages Using a Generic Quality Framework. In: K. Siau (ed.); Advanced Topics in Database Research. Idea Group Inc. London, 2006.

- OMG (2009) Object Management Group; Business Process Modeling Notation – Standard Document. URL: [www.omg.org/spec/BPMN/1.2](http://www.omg.org/spec/BPMN/1.2). Accessed 12.07.2011.
- OUM AND WATERS (1999) T.H. Oum and W.G. Waters; A Survey of Productivity and Efficiency Measurement in Rail Transport. *Journal of Transport Economics and Policy*. 33 (1999), pp. 9-42.
- ÖZENER AND ERGUN (2008) O. Özener and Ö. Ergun; Allocating Costs in a Collaborative Transportation Procurement Network. *Transportation Science*. 42 (2008), No. 2, pp. 146-165.
- PATTON (2002) M.Q. Patton; *Qualitative Research & Evaluation Methods*. Sage Publications. Thousand Oaks, 2002.
- PERRIN (2011) N. Perrin; *Die Bahn als Vorteil in der Logistik. Betriebswirtschaftliche Kennzahlen*. ETH Ringvorlesung, 17.10.2011, Zürich.
- PREISSLER (2008) P.R. Preissler; *Betriebswirtschaftliche Kennzahlen*. Oldenbourg Wissenschaftsverlag. München, 2008.
- PROKOPENKO (1987) J. Prokopenko; *Productivity Management*. International Labour Organisation. Geneva, 1987
- ROITSCH AND MEYR (2008) M. Roitsch and H. Meyr; *Oil Industry*. In: H. Stadler and Ch. Kilger (eds.); *Supply Chain Management and Advanced Planning*. Springer Verlag. Berlin, 2008.
- QGI (2010) QGI Consulting; *Railway Car Order and Car Supply Processes*. URL: <http://www.qgiconsulting.com/pdf/RailwayCarOrderandCarSupplyProcesses.pdf>. Accessed 09.02.2011.
- RANFTL (1978) R. Ranftl; *R&D Productivity*. Hughes Aircraft Company. Culver City, 1978.
- RICHEY (1998) T. Richey; *General Morphological Analysis – A general method for non-quantified modelling*. Conference on Operational Analysis. Brussels, 1998.
- ROHDE ET AL. (2000) J. Rohde, H. Meyr, and M. Wagner; *Die Supply Chain Planning Matrix*. *PPS Management*. 5 (2000), pp. 10-15.
- RUMBAUGH ET AL. (2005) J. Rumbaugh, I. Jacobson, and G. Booch; *The Unified Modelling Language Reference Manual*. Pearson Education. Boston, 2005.
- SBB (2010-1) SBB and BLS; *List of Infrastructure Services 2011*. URL: [http://mct.sbb.ch/mct/en/leistungskatalog\\_2011\\_en.pdf](http://mct.sbb.ch/mct/en/leistungskatalog_2011_en.pdf). Accessed 16.02.2011.



- SBB (2010-2) SBB; Die SBB in Zahlen und Fakten 2010. URL: <http://www.sbb.ch/sbb-konzern/medien/publikationen/vademecum.html>. Accessed 22.02.2012.
- SBB (2012) SBB and BLS; Leistungskatalog Infrastruktur 2013. URL: [http://www.sbb.ch/content/sbb/de/desktop/sbb-konzern/sbb-als-geschaeftpartner/zugang-zum-bahnnetz/onestopshop/leistungen-preise/\\_jcr\\_content/contentPar/downloadlist/downloadList/leistungskatalog\\_sbb\\_1.spooler.download.pdf](http://www.sbb.ch/content/sbb/de/desktop/sbb-konzern/sbb-als-geschaeftpartner/zugang-zum-bahnnetz/onestopshop/leistungen-preise/_jcr_content/contentPar/downloadlist/downloadList/leistungskatalog_sbb_1.spooler.download.pdf). Accessed 02.05.2012.
- SBB CARGO (2010) SBB Cargo; Gesamtarbeitsvertrag 2007 – 2010.
- SBB CARGO (2011) SBB Cargo; Preise und Konditionen Güterwagen. URL: [http://www.sbbcargo.com/de/angebot/transportleistungen/einzelwagen\\_wagengruppen.html](http://www.sbbcargo.com/de/angebot/transportleistungen/einzelwagen_wagengruppen.html). Accessed 28.03.2012.
- SCHEER (1992) A.W. Scheer; Architektur integrierter Informationssysteme. Springer Verlag. Berlin, 1992.
- SCHERMERHORN (1986) J. R. Schermerhorn; Management for productivity. John Wiley & Sons. Canada, 1986.
- SCHICK (2009) U. Schick; Logistikketten verstehen. Heinrich Vogel Verlag. München, 2009.
- SCHÖNSLEBEN (2001) P. Schönsleben; Integrales Informationsmanagement. Springer Verlag. Berlin, 2001.
- SCHÖNSLEBEN (2004) P. Schönsleben; Integral Logistics Management. St. Lucie Press. Boca Raton, 2004.
- SCI (2010) SCI Verkehr GmbH; Dieseltriebwagen/ Elektrotriebwagen – weltweite Marktentwicklung. URL: [www.sci.de/uploads/tx\\_edocuments/Produktinformation\\_MC\\_Triebwagen\\_01.pdf](http://www.sci.de/uploads/tx_edocuments/Produktinformation_MC_Triebwagen_01.pdf). Accessed 21.02.2012.
- SEAR (1993) T.N. Sear; Logistics Planning in the Downstream Oil Industry. Journal of the Operational Research Society. 44 (1993), No. 1, pp. 9 - 17.
- SEIDLMEIER (2004) H. Seidlmeier; Process Modelling with ARIS – A Practical Introduction. Vieweg Verlag. Wiesbaden, 2004.
- SIMON (2005) W. Simon; GABALs grosser Methodenkoffer: Managementtechniken. Gabal Verlag. Offenbach, 2005.
- SLACK ET AL. (2007) N. Slack, S. Chambers, and R. Johnston; Operations Management. Pearson Education Limited. Harlow, 2007.

- SMITH (1995) E. A. Smith; The Productivity Manual. Gulf Publishing Company. Houston, 1995.
- SPECKER (2005) A. Specker; Modellierung von Informationssystemen. vdf Hochschulverlag. Zürich, 2005.
- SSHV(2011-1) Schweizerischer Stahl- und Haustechnikhandelsverband; Produktion – Die Stahlkette. URL: <http://www.stahlpromotion.ch/de/traegerverbaende/sshv/produktion.html>. Accessed: 08.11.2011.
- SSHV(2011-2) Schweizerischer Stahl- und Haustechnikhandelsverband; Stahlmarkt-Statistik 2009/2010. URL: <http://www.sshv.ch>. Accessed: 07.11.2011.
- STATISTISCHES BUNDESAMT (2008) Statistisches Bundesamt (Destatis); NST 2007 – Einheitliches Güterverzeichnis für die Verkehrsstatistik. Wiesbaden, 2008.
- TELANG AND TELANG (2010) A. D. Telang and A. Telang; Comprehensive Maintenance Management. PHI Learning Private Limited. New Delhi, 2010.
- THOMAS (2003) R.M. Thomas; Blending qualitative & quantitative research methods in theses and dissertations. Corwin Press. Thousand Oaks, 2003.
- THOMMEN (2008) J.-P. Thommen; Managementorientierte Betriebswirtschaftslehre. Versus Verlag. Zürich, 2008.
- THURNER (2004) V. Thurner; Formal fundierte Modellierung von Geschäftsprozessen. Logos Verlag. Berlin, 2004.
- TYAN AND WANG (2003) J.-C. Tyan and F.-K. Wang; Applying collaborative transportation management models in global third-party logistics. International Journal of Computer Integrated Manufacturing. 16 (2003), No. 4, pp. 283-291.
- UIC (2012) International Union of Railways (UIC); Rail Freight Portal. URL: [www.railfreightportal.com](http://www.railfreightportal.com). Accessed 18.04.2012
- UIRR (2011) International Union of combined Road-Rail transport companies. URL: [www.uirr.com](http://www.uirr.com). Accessed 07.02.2011.
- UN/ECE 2001 United Nations – Economic Commission for Europe (UN/ECE); Terminology on Combined Transport. New York and Geneva, 2001.
- UVEK (2011) Eidg. Departement für Umwelt, Verkehr, Energie und Kommunikation (UVEK); Bericht über die Verkehrsverlagerung im Dezember 2011. URL:

- www.news.admin.ch/NSBSubscriber/message/attachments/25198.pdf. Accessed 07.02.2012.
- VESTER (1976) F. Vester; Ballungsgebiete in der Krise: eine Anleitung zum Verstehen und Planen menschlicher Lebensräume mit Hilfe der Biokybernetik. Deutsche Verlags-Anstalt, 1976.
- VESTER AND HESLER (1982) F. Vester and A.v. Hesler; Sensitivity Model. Umlandverband Frankfurt. Frankfurt/Main, 1982.
- VICS (2004-1) VICS; Collaborative Planning, Forecasting and Replenishment. URL: [http://www.vics.org/docs/standards/CPFR\\_Overview\\_US-A4.pdf](http://www.vics.org/docs/standards/CPFR_Overview_US-A4.pdf). Accessed 03.02.2011.
- VICS (2004-2) VICS; Collaborative Transportation Management. URL: <http://www.idii.com/wp/ctm.pdf>. Accessed 03.02.2011.
- VSSV (2011) Verband Schweizerischer Schrottverbraucher; Nomenklatur für Stahlwerkschrott. URL: [http://www.vssv.ch/inhalt/alles\\_ueber\\_eisenschrott/sorten.html](http://www.vssv.ch/inhalt/alles_ueber_eisenschrott/sorten.html). Accessed 09.11.2011.
- WEIDMANN ET AL. (2007) U. Weidmann, J. Wichser, N. Fries, P. Schmidt, and H. Schneebeili; Studie zu einem neuen schweizerischen Trassenpreissystem. Scientific Series of the Institute for Transport Planning and Systems, 135, ETH Zürich. Zürich, 2007.
- WENTWORTH (1922) C. Wentworth; A Scale of Grade and Class Terms for Clastic Sediments. *The Journal of Geology*. 30 (1922), No. 5, pp. 377-392.
- WESKE (2007) M. Weske; *Business Process Management: Concepts, Languages, Architectures*. Springer Verlag. Berlin, 2007.
- WEYERS (2007) A. Weyers; *Güterwagenmanagement – Analyse wesentlicher Potenziale des Eisenbahngüterverkehrs anhand von Simulationen*. Kölner Wissenschaftsverlag. Köln, 2007.
- WHITE (2004) S. White; *Process Modeling Notations and Workflow Patterns*. In: L. Fischer (ed.); *Workflow Handbook 2004*. Future Strategies Inc. Lighthouse Point, 2008.
- WHITE AND MIERS (2008) S. White and D. Miers; *BPMN – Modeling and Reference Guide*. Future Strategies Inc. Lighthouse Point, 2008.

- WHIPPLE AND RUSSEL (2007) J. M. Whipple and D. Russel; Building supply chain collaboration: a typology of collaborative approaches. *The International Journal of Logistics Management*. 18 (2007), No. 2, pp. 174-196.
- WICANDER AND MONROE (2006) R. Wicander and J. S. Monroe; *Essentials of Geology*. Thomson Brooks/Cole. Belmont, 2006.
- WICHSER (2010) J. Wichser; *System- und Netzplanung – Logistik und Güterverkehr (Band 1.3)*. Lecture Notes. Institute for Transport Planning and Systems. ETH Zurich. Zurich, 2010.
- WIEGMANS ET AL. (2007) B.W. Wiegman, A. Rogier, and T. Donders; Benchmarking European Rail Freight Transport Companies. *Transportation Journal*. 46 (2007), No. 2, pp. 19-34.
- WINTER (2000) S. Winter; Quantitative vs. Qualitative Methoden. URL: [http://imihome.imi.uni-karlsruhe.de/nquantitative\\_vs\\_qualitative\\_methoden\\_b.html](http://imihome.imi.uni-karlsruhe.de/nquantitative_vs_qualitative_methoden_b.html). Accessed 07.03.2012.
- WISSEMA (1976) J. Wissema; Morphological analysis: Its application to a company TF investigation. *Future*. 8 (1976), No. 2, pp. 146-153.
- WURST (2004) Ch. Wurst; *Kapazitätssteuerung in Dienstleistungsunternehmen – Optimierungsansätze des Güterwagenmanagements*. Kassel University Press. Kassel, 2004.
- YU AND LIN (2008) M.M. Yu and E.T.J. Lin; Efficiency and effectiveness in railway performance using a multi-activity network DEA model. *Omega*. 36 (2008), pp. 1005-1017.
- YUAN ET AL. (2006) C.-Y. Yuan, C.-M. Feng, and L.-F. Sun; Application of Collaborative Transportation Management to Business Global Logistics: A study of EMS corporations and 3PL service providers in Taiwan. *International Conference of Business and Information*. Singapore, 2006.
- YUAN (2007) C.-Y. Yuan; *The effects of Collaborative Transportation Management on Business Performance and Supply Chain Dynamics*. National Chiao Tung University. Taiwan, 2007.
- ZWICKY (1969) F. Zwicky; *Discovery, invention, research through the morphological approach*. Macmillan. New York, 1969.