

Performance-oriented Integration of Combined Transport into Supply Chain Concepts

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Abstract

The thesis in hand develops a conceptual framework and offers practical recommendations on the performance-oriented integration of combined transport (CT) into supply chain (SC) concepts to overcome recent challenges in unimodal road transport, including sustainability and performance orientation.

Recent SC concepts are characterised by attempts to reduce inventory and to simultaneously increase flexibility and reliability. Therefore, the procurement, production and distribution concepts of shippers, suppliers and third party logistics service providers are increasingly connected and synchronised to meet the demands of end customers. At the same time, companies focus on financial key figures and increasing corporate value. SC activities are evaluated according to their effects on company value, too. The analysis of recent SC concepts shows that transport actors are often not integrated members of these SC concepts. The thesis in hand exploits this imperfection for the integration of CT into SC concepts. It is assumed that the tight integration of material and information flows opens up time buffers and increases coordination flexibility necessary for CT integration.

Current developments make the combination of rail and road transport a promising possibility to solve the conflict between recent forces, such as sustainability, problems in unimodal road transport and changing SC performance (SCP) requirements – even for distances below 100 km. Nevertheless, CT means the involvement of additional SC actors and additional processes.

A conceptual framework based on configuration theory provides propositions on the integration of CT into different SC concept types. The framework proposes an innovative perspective on the integration problem. The central assumption is that aiming at SCP an adaptation of the SC concept oriented to the characteristics of CT is necessary. The thesis provides practical recommendations on concrete adaptation points to improve the fit between SC and CT concept and the usage of integrative measures and instruments.

A simulation study based on the SC concept of a Swiss retailer enhances and validates the findings of the conceptual framework. The effect on SCP of the integration of regular line CT into a lean SC concept is analysed using an object-oriented, discrete event simulation. Specifically, the simulation study analyses the influence of adaptations on the distribution concept and production concept to reveal time buffers and to reduce coordination effort between SC actors.

Zusammenfassung

Moderne Supply Chain (SC)-Konzepte sind durch den Versuch gekennzeichnet, Lagerbestände weitestgehend zu minieren und gleichzeitig Flexibilität und Zuverlässigkeit zu erhöhen. Dabei werden die Beschaffungs-, Produktions- und Distributionskonzepte verladender Unternehmen sowie von Zulieferern und Logistikdienstleistungsunternehmen immer stärker integriert und synchronisiert. Gleichzeitig konzentrieren sich die Unternehmen zunehmend auf finanzielle Kennzahlen und richten ihre Aktivitäten auf eine kontinuierliche Steigerung des Unternehmenswertes aus. Auch SC-Aktivitäten werden hinsichtlich ihrer so genannten Performance-Wirkung analysiert. Die Analyse aktueller SC-Konzepte zeigt, dass Transportakteure oftmals keine integrierten Mitglieder dieser SCs sind. Die vorliegende Arbeit erschliesst diese Lücke für die Integration Kombiniertes Verkehre (KV) in die SC-Konzepte, um so Nachhaltigkeitsforderungen und Problemen im Strassenverkehr zu begegnen. Zwar erfordert die Integration von KV auch die Einbindung weiterer SC-Akteure sowie zusätzliche Prozesse. Jedoch wird angenommen, dass die enge Integration der Material- und Informationsflüsse benötigte Zeitkontingente eröffnet und die unternehmensübergreifende Koordinationsflexibilität auf das erforderliche Mass erlaubt.

Der auf der Konfigurationstheorie basierende konzeptionelle Rahmen zeigt eine Reihe von Propositionen zur Integration unterschiedlicher KV-Konzepte in verschiedene SC-Konzepttypen hinsichtlich der Wirkung auf unternehmensübergreifende SC-Performance. Mit der zentralen Annahme, dass eine gezielte Ausrichtung des SC-Konzepts auf die Charakteristika des KV zu einer Erhöhung der SC-Performance führt, wird in der vorliegenden Arbeit eine innovative Sichtweise auf das Integrationsproblem präsentiert. Dazu liefert die Arbeit konkrete Handlungsempfehlungen und zeigt Anpassungspunkte auf, um den so genannter "Fit" zwischen SC-Konzept, KV-Konzept und konkreten, situationsspezifischen Massnahmen und Instrumenten zu verbessern.

Eine auf dem SC-Konzept eines Schweizerischen Handelsunternehmens basierende Simulationsstudie erweitert und validiert die Ergebnisse des entwickelten konzeptionellen Rahmens. Mittels einer objektorientierten, ereignisdiskreten Materialflusssimulation wird die SC-Performance-Wirkung der Integration eines KV-Konzeptes, das auf regelmässigen und terminierten Zugverkehren basiert, auf eine leane SC analysiert. Dabei werden insbesondere der Einfluss bestimmter Anpassungen von Beschaffungs-, Produktions- und Distributionskonzepten untersucht, um so für die KV-Integration erforderliche Zeitkontingente zu erschliessen und den Koordinationsaufwand zwischen den SC-Akteuren zu reduzieren.

Table of Contents

Abstract	I
Zusammenfassung	II
Table of Contents	III
List of Figures	VI
List of Tables	VIII
List of Abbreviations	X
1 Integration of Combined Transport into Supply Chain Concepts from a Performance Perspective: Need for Action	1
<i>1.1 Problem Formulation and Research Questions</i>	<i>1</i>
<i>1.2 Scientific-Theoretical Positioning and Research Design</i>	<i>5</i>
<i>1.3 Research Process and Thesis Outline</i>	<i>8</i>
2 Problem Concretisation - SCP Orientation Encourages the Integration of CT into SC Concepts	12
<i>2.1 Needs, Challenges and Instruments for SC Integration</i>	<i>12</i>
2.1.1 Need for SC Integration	13
2.1.2 Central Elements and the Fields of SC Integration	17
2.1.3 Normative, Operative and Strategic Challenges of SC Integration	18
2.1.3.1 Overview on SC Integration Challenges	18
2.1.3.2 Challenge 1: Main Objectives of Integrated SCs – Problems of SCM Conception	19
2.1.3.3 Challenge 2: Differing Operative Objectives and Problems of Shippers and CT Actors	24
2.1.3.4 Challenge 3: Focus on Individual Company Value Growth	29
2.1.4 Vulnerability of Integrated SC Concepts	29
2.1.5 Measures and Instruments for SC Integration	33
<i>2.2 Coping with CT Complexity in SCs</i>	<i>41</i>
2.2.1 Application Fields of CT	41
2.2.2 Service Complexity of Combined Transport Concepts	46
2.2.2.1 Inherent Challenges of Combined Transport	46
2.2.2.2 Diversity of CT Services	47
2.2.2.3 Diversity of CT Actors	49
2.2.2.4 Processes and Structure of CT Services	53
2.2.2.5 Service Character of CT Services	55
2.2.3 External Factors Increasing the Complexity of CT	56
2.2.3.1 Changing Shippers' Performance Requirements Challenging CT Services	56
2.2.3.2 Impact of Transport Policy on CT	58
2.2.3.3 Competitive Situation of CT and Unimodal Road Transport	66
2.2.4 Integrated Management of CT Concepts	68
<i>2.3 SCP Orientation – Consideration of Strategic and Operational Key Figures</i>	<i>73</i>
2.3.1 Fundamentals of Performance Orientation	74
2.3.2 Performance Understanding in a SC Context	77
2.3.3 Suitability of SCP as a Target System for the Integration of CT into SC Concepts	81
2.3.4 Development of a Target System for the Evaluation of CT Integration into SC Concepts	87
<i>2.4 Configuration Theory as Theoretical Research Approach for Integrating CT into SC Concepts</i>	<i>89</i>
2.4.1 Meaning of Theory Application for Application-Oriented Research	89
2.4.2 Theoretical Solution Approaches towards SC Integration	90
2.4.3 Selection of Theoretical Approaches with regard to the Research Problem and Perspective	92

2.4.4	Configuration Theory as an Explanation Approach for the Performance-oriented CT Integration into SC Concepts	94
2.4.4.1	Basics of Situative Theory	94
2.4.4.2	Configuration Theory as an Advancement of Situative Theory	95
2.4.4.3	Application of Configuration Theory to the Problem of the Performance-Oriented Integration of CT into SC Concepts	98
2.5	<i>Intermediate Findings</i>	99
3	CT as an Element of SC Concepts	102
3.1	<i>SC Concepts as the Operationalisation of SC Strategies</i>	102
3.1.1	SC Strategies as the Basis for SC Concept Configuration	102
3.1.2	Classification Approaches for SC Strategies	105
3.1.3	Impact of SC Strategy on the Configuration of SC Sub-Concepts	110
3.1.4	Elements and Structures of SC Concepts	110
3.1.4.1	SC Concept Configuration in a Lean SC	113
3.1.4.2	SC Concept Configuration in an Agile SC	115
3.1.4.3	SC Concept Configuration in a Leagile SC	117
3.2	<i>Development of a Classification of SCP Requirements regarding Transport Concepts</i>	119
3.3	<i>Configuration of SC Concepts</i>	126
3.3.1	Transport Concepts as Linking and Embedded Elements of SC Concepts	126
3.3.2	Impact of Procurement Concepts on the Configuration of Transport Concepts	131
3.3.2.1	Meaning of the Procurement Concepts for SCP	131
3.3.2.2	Structures and Processes of Procurement Concepts	133
3.3.2.3	Classification and Configuration of Procurement Concepts – Identification of Design Variables relevant for CT Integration	135
3.3.3	Impact of Production Concept Configuration on Transport Concepts	141
3.3.3.1	Meaning of the Production Concept for SCP	141
3.3.3.2	Structures and Processes of Production Concepts	142
3.3.3.3	Classification and Configuration of Production Concepts – Identification of Design Variables relevant for CT Integration	143
3.3.4	Impact of Distribution Concepts on the Configuration of Transport Concepts	148
3.3.4.1	Meaning of the Distribution Concept for SCP	148
3.3.4.2	Structures and Processes of Distribution Concepts	149
3.3.4.3	Classification and Configuration of Distribution Concepts – Identification of Design Variables relevant for CT Integration	153
3.4	<i>Development of a CT Concept Typology - Classification using SCP Profiles</i>	156
3.5	<i>Intermediate Findings</i>	160
4	Conceptual Research Framework of Performance-oriented CT Integration into SC Concepts	163
4.1	<i>Central Aspects of the Development of Research Propositions on the Performance-oriented CT Integration</i>	163
4.2	<i>Development of a Conceptual Research Framework and Deduction of Propositions on the Performance-oriented CT Integration into SC Concepts</i>	165
4.2.1	Identification of Central Constructs and Framework Conditions	165
4.2.2	Middle Range Constructs — Elements and Dimensions of Central Constructs	167
4.2.3	Manifest, Observable Variables	169
4.2.4	Moderating Variables of CT Integration into SC Concepts	172
4.3	<i>Cause-and-Effect Relationships between the Elements of CT and SC Concepts - Deduction of Methodological and Instrumental Implications</i>	174
4.3.1	Step 1: Identification of Integration Points for CT into SC Concepts	174
4.3.2	Step 2: Impact of SC Strategy, SC Concept Configuration and SCP Requirements Profiles on CT Integration	176

4.3.3	Step 3: Identification of Adaptation Points for CT Concept Integration	179
4.3.4	Step 4: Situation-specific Choice of Integrative Measures and Instruments for Performance-oriented CT Integration into SC Concepts	183
4.4	<i>Intermediate Findings</i>	191
5	Performance-oriented Integration of Combined Line Transport into a Lean SC - A Simulation Study	194
5.1	<i>Research Design for the Simulation Study</i>	195
5.1.1	Scientific-theoretical Positioning of the Simulation Methodology	195
5.1.2	Advantages, Restrictions and Application Fields of Simulation Methodology	196
5.1.3	Quality Criteria for Simulation Studies	199
5.1.4	Structure and Classification of Simulation Models	201
5.1.5	Application Fields of the Simulation Methodology in Transport and SCM Science	203
5.1.6	Discrete Event Simulation as the Research Methodology for the Analysis of Performance-oriented Integration of CT into SC Concepts	205
5.2	<i>Process Model for the Simulation Model Development</i>	207
5.3	<i>Step 1: Problem Formulation and Target Definition</i>	209
5.3.1	Scope and Target Definition	209
5.3.2	Problem Formulation - Understanding the Initial SC Concept	210
5.3.3	CT Integration Scenarios	212
5.3.4	Performance Indicators for the Evaluation of Simulation Scenarios	215
5.3.5	Development of Statements on Expected Simulation Results	217
5.4	<i>Step 2: Data Gathering and Editing for Model Configuration and Validation</i>	220
5.5	<i>Step 3: Development, Validation and Verification of the Simulation Model</i>	229
5.5.1	Conceptual Model	230
5.5.2	Simulation Model	235
5.5.3	Validation and Verification	238
5.6	<i>Step 4: Experimental Plan and Setup of Experiments</i>	241
5.7	<i>Step 5: Description and Analysis of Simulation Results</i>	242
5.7.1	Basic Scenario – Modelling the ‘as-is’ Situation	242
5.7.2	CT Scenario I - Integration without Adaptation to the SC Concept	252
5.7.3	CT Scenario II – Production Concept Adaptation	262
5.7.4	CT Scenario III – Distribution Concept Adaptation	270
5.7.5	Discussion of Simulation Results	277
5.7.6	Limitations, Validity and Generalisability of Findings	285
5.8	<i>Intermediate Findings</i>	288
6	Implications for Science and Practice on the Performance-oriented Integration of CT into SC Concepts	291
6.1	<i>Management Implications</i>	291
6.2	<i>Scientific Implications</i>	294
6.3	<i>Limitations and Further Research</i>	296
	References	302

List of Figures

Figure 1 - 1: Working definitions of central constructs.	4
Figure 1 - 2: Application-oriented research process and thesis outline.	11
Figure 2 - 1: Linking of formal and content targets of SCM.	22
Figure 2 - 2: Differences in the operative challenges of selected SC actors.	25
Figure 2 - 3: Road infrastructure shortages in Germany.	31
Figure 2 - 4: Management components of SC integration.	33
Figure 2 - 5: Overview of the technical and organisational management components derived from the literature.	34
Figure 2 - 7: Alpine transit by unaccompanied CT.	45
Figure 2 - 8: Schematic depiction of CT material (black) and information flow and additional planning and control processes (blue).	53
Figure 2 - 9: Overview of recent and expected CT terminal capacity shortages in Europe.	64
Figure 2 - 10: Schematic costs for unimodal, combined and multimodal road transport concepts.	67
Figure 2 - 11: Efficiency and effectiveness dimensions of performance.	76
Figure 2 - 12: Characterisation and ideal cause-and-effect relationships between the targets of SCP management.	80
Figure 2 - 13: Performance perspective for the integration of CT into SC concepts.	86
Figure 2 - 14: Target system of SCP and performance indicators for the integration of CT into SC concepts.	88
Figure 3 - 1: Generic SC strategies.	109
Figure 3 - 2: Transport structure for full and less than full truckloads.	129
Figure 3 - 3: SC structure for a packaged goods transport.	130
Figure 3 - 4: Generic procurement strategies according to supply risk and profit impact.	134
Figure 3 - 5: Overview of incoterms 2010.	139
Figure 3 - 6: Basic structures of distribution systems.	151
Figure 4 - 1: Central constructs of the CT integration into SC concepts.	167
Figure 4 - 2: Middle range constructs of the performance-oriented CT integration into SC concepts.	168
Figure 4 - 3: Manifest, observable variables of CT integration into SC concepts.	170
Figure 4 - 4: Conceptual research framework of CT integration into SC concepts.	172
Figure 4 - 5: Integrative measures and instruments as moderating variables for CT integration.	173
Figure 4 - 6: Schematic illustration of the integration points of CT concepts.	175
Figure 4 - 7: General applicability of CT concepts according to different SC strategies.	177
Figure 5 - 1: Schematic of the as-is situation – <i>Manor</i> distribution network (Western Switzerland).	212
Figure 5 - 2: Schematic scenario – <i>Manor</i> distribution network including CT (Western Switzerland).	214
Figure 5 - 3: Performance indicators for the evaluation of simulation scenarios.	216
Figure 5 - 4: Comparison of CO ₂ , NO _x and particle emissions for different transport modes (under consideration of all climate-related effects of air cargo).	222
Figure 5 - 5: Example demand history for delivery to the store in Geneva from DC Hochdorf for prioritised goods from January – September 2010 in pallet equivalents.	227
Figure 5 - 6: Demand in pallet equivalents per weekday for prioritised goods for the store in Yverdon from DC Möhlin.	228
Figure 5 - 7: Conceptual model simulation scenario with CT.	231
Figure 5 - 8: Data model for the simulation study (simplified UML notation).	232
Figure 5 - 9: Screenshot from the simulation model in Flexsim.	236
Figure 5 - 10: Example inventory course for delivery to the Chavannes store with goods from DC Hochdorf.	237
Figure 5 - 11: Conceptual model validation and verification.	239
Figure 5 - 12: Mean utilisation per primary transport route and weekday for the normal demand situation.	243

Figure 5 - 13: Mean utilisation per additional transport route and weekday for the normal demand situation.	244
Figure 5 - 14: Average utilisation of primary transport vehicles for different transport routes and demand situations.	245
Figure 5 - 15: Average utilisation of primary transport vehicles for different transport routes and demand situations.	245
Figure 5 - 16: Transport time elements per store for DC Hochdorf.	246
Figure 5 - 17: Transport time elements per store for DC Möhlin.	247
Figure 5 - 18: Average lead time elements for different demand situations.	247
Figure 5 - 19: Average inventory in the transport between DC and the stores.	248
Figure 5 - 20: Average inventory for different demand situations.	249
Figure 5 - 21: CO ₂ emissions per transport route.	250
Figure 5 - 22: Average deviation and delay for different stores and DCs.	251
Figure 5 - 23: Utilisation of trains for CT scenario I.	255
Figure 5 - 24: Transport time elements per store for DC Hochdorf for CT scenario I and the normal demand situation.	255
Figure 5 - 25: Transport time elements per store for DC Möhlin for CT scenario I and the normal demand situation.	256
Figure 5 - 26: Comparison between average lead time elements between basic and CT scenario I.	256
Figure 5 - 27: Lead time comparison of basic and CT scenario I for different demand levels.	257
Figure 5 - 28: Comparison of inventory levels per store for CT scenario I and the basic scenario.	258
Figure 5 - 29: Comparison of inventory levels for CT scenario I for the different demand situations.	258
Figure 5 - 30: CO ₂ emissions per transport route – comparison of basic scenario and CT scenarios.	259
Figure 5 - 31: Deviation and delay of deliveries per store and DC for CT scenario I.	261
Figure 5 - 32: Adherence to schedules regarding delays - comparison between basic and CT scenario I.	262
Figure 5 - 33: Effect of production concept adaptation on train schedule and delivery windows.	264
Figure 5 - 34: Utilisation of trains for CT scenario II.	265
Figure 5 - 35: Transport time elements per store for CT scenario II for the normal demand situation.	266
Figure 5 - 36: Comparison of lead time for different demand situations between CT scenario I and CT scenario II.	266
Figure 5 - 37: Average inventory in the transport between DC and stores for CT scenario II in comparison with CT scenario I.	267
Figure 5 - 38: Comparison of lead time elements for CT scenario II for different demand situations.	267
Figure 5 - 39: Comparison of delay between CT scenario I and CT scenario II.	268
Figure 5 - 40: Comparison of adherence to schedules for different demand situations.	269
Figure 5 - 41: Effect of distribution concept adaptation to train schedule for transport route H 75 (CT scenario III).	271
Figure 5 - 42: Comparison of lead times of CT scenario I and CT scenario III for different demand situations.	272
Figure 5 - 43: Comparison of lead time elements between CT scenario I and CT scenario III.	273
Figure 5 - 44: Average inventory in the transport between DC and stores coming from DC Hochdorf for CT scenario III.	273
Figure 5 - 45: Inventory levels for different demand situations - CT scenario III.	274
Figure 5 - 46: Comparison of delay between CT scenario I and CT scenario III.	274
Figure 5 - 47: Comparison of adherence to schedules regarding delays for different demand situations.	275
Figure 5 - 48: Comparison of lead time elements for CT scenario III and CT scenario IIIa.	276
Figure 5 - 49: Comparison of inventory levels for CT scenario III and IIIa for different demand situations	277
Figure 5 - 50: Comparison of lead time for different simulation scenarios.	278
Figure 5 - 51: Comparison of adherence to schedules regarding delayed deliveries.	279
Figure 5 - 52: Comparison of inventory levels for all scenarios and for different demand situations.	281

List of Tables

Table 1 - 1: Scientific-theoretical positioning of the thesis in hand.	7
Table 2 - 1: Literature review of integrative measures from the field of I&C flow facility structure.	36
Table 2 - 2: Literature review of integrative measures from the field of workflow and activity structure.	38
Table 2 - 3: Literature review of integrative measures from the field of organisational structure.	39
Table 2 - 4: Literature review of integrative measures from the field of planning and control methods.	40
Table 2 - 5: Literature review of integrative measures from the field of product flow facility structure.	40
Table 2 - 6: Transport quantities in CT (unaccompanied) in 2009 in tons and TEU.	44
Table 2 - 7: Systematisation of CT.	48
Table 2 - 8: Comparison of shippers' performance expectations and CT service compliance.	58
Table 2 - 9: Classification criteria for CT business models.	70
Table 2 - 10: Selected performance indicators at the actor's level.	84
Table 2 - 11: Selected performance indicators at the dyadical level.	85
Table 2 - 12: Selected performance indicators at the concept level.	86
Table 2 - 13: Comparison of shippers' performance requirements and CT characteristics.	100
Table 3 - 1: Time-related SCP requirements depending on the SC strategy.	121
Table 3 - 2: Space-related SCP requirements depending on the SC strategy.	122
Table 3 - 3: Shipment size and transport quantity SCP requirements depending on the SC strategy.	122
Table 3 - 4: Product type-related SCP requirements depending on the SC strategy.	123
Table 3 - 5: Cost-related SCP requirements depending on the SC strategy.	124
Table 3 - 6: Flexibility-related SCP requirements depending on the SC strategy.	124
Table 3 - 7: Reliability-related SCP requirements depending on the SC strategy.	125
Table 3 - 8: SCP requirements profiles derived from SC strategy.	125
Table 3 - 9: Classification criteria for procurement concepts with regard to the impact on transport concepts.	136
Table 3 - 10: Impact of procurement concept configuration on SCP requirements.	141
Table 3 - 11: Classification criteria for production concepts with regard to the impact on transport concepts.	144
Table 3 - 12: Impact of production concept configuration on SCP requirements.	147
Table 3 - 13: Classification criteria for distribution concepts with regard to the impact on transport concepts.	153
Table 3 - 14: Impact of distribution concept configuration on SCP requirements.	156
Table 3 - 15: Characteristics of the CT concept 'line transport - regular booking'.	158
Table 3 - 16: Characteristics of the CT concept 'sporadic usage of line relation'.	159
Table 3 - 17: Characteristics of the CT concept 'network relation'.	160
Table 3 - 18: Overview on CT concept and suitable application fields.	161
Table 3 - 19: SCP requirements profiles of the three CT concept types.	162
Table 4 - 1: Identification of relevant concepts depending on the integration point.	176
Table 4 - 2: Applicability of CT types according to SC strategy and integration point.	179
Table 4 - 3: Example of contrasting lean SCP requirements profile and the performance profile of line transport concept with regular booking performance profile.	180
Table 4 - 4: Example of the misfit of SCP requirements and CT performance profile.	180
Table 4 - 5: Adaptation points for SCP requirements regarding time.	181
Table 4 - 6: Adaptation points according to performance dimension, criterion and involved SC sub-concept.	182
Table 4 - 7: Overview of analysed integrative measures and instruments and abbreviations.	183
Table 4 - 8: Impact of integrative measures and instruments on time-related SCP requirements.	185
Table 4 - 9: Impact of integrative measures and instruments on space-related SCP requirements.	186

Table 4 - 10: Impact of integrative measures and instruments on shipment size and transport quantity related SCP requirements.	187
Table 4 - 11: Impact of integrative measures and instruments on cost related SCP requirements.	188
Table 4 - 12: Impact of integrative measures and instruments on product related SCP requirements.	189
Table 4 - 13: Impact of integrative measures and instruments on flexibility related SCP requirements.	190
Table 4 - 14: Impact of integrative measures and instruments on reliability related SCP requirements.	191
Table 4 - 15: Applicability of CT types according to SC strategy and integration point.	192
Table 4 - 16: Summary - impact of integrative measures and instruments on SCP requirements.	193
Table 5 - 1: Focus of simulation study.	209
Table 5 - 2: Sites modelled in the simulation.	221
Table 5 - 3: Emission factors for rail transport.	223
Table 5 - 4: Standardised inclination profile.	224
Table 5 - 5: Extract of route segments defined for the simulation with distance, street profile and transport time.	225
Table 5 - 6: Primary transport routes, transport resources and start times.	226
Table 5 - 7: Average demand for prioritised goods per weekday and store.	229
Table 5 - 8: Experimental plan for the simulation study.	242
Table 5 - 9: Average emissions for transport route H 60.	249
Table 5 - 10: Emissions per transport route.	250
Table 5 - 11: Emissions for a one-week simulation run.	250
Table 5 - 12: Overview of key figures regarding the adherence to schedules for the basic scenario.	252
Table 5 - 13: Extract of route plan for the CT scenario I (complete list in Appendix B-II).	253
Table 5 - 14: Train schedule between Härkingen terminal and Daillens terminal.	253
Table 5 - 15: Comparison of emissions for transport route H 60 for CT scenario I.	259
Table 5 - 16: Emissions for CT scenario I in comparison with the basic scenario - calculation of possible savings for a one-week simulation run.	260
Table 5 - 17: Adaptations to the production concept.	264
Table 5 - 18: Overview of key figures regarding the adherence to schedules for CT scenario II.	269
Table 5 - 19: Adaptations to the distribution concept for CT scenario III.	271
Table 5 - 20: Comparison of projected emission factors and possible savings for one year.	280

List of Abbreviations

3PL	Third Party Logistics Service Provider
4PL	Fourth Party Logistics Service Provider
AMMPL	Association Materials Management, Purchasing and Logistics
APS	Advanced Planning System
BSC	Balanced Scorecard
BOM	Bill of Material
B2B	Business-to-Business
B2C	Business-to-Customer
CIF	Cost, Insurance and Freight
ConWiP	Constant Work in Process
CPFR	Collaborative Planning, Forecasting and Replenishment
CRM	Customer Relationship Management
CSCMP	Council of Supply Chain Management Professionals
CT	Combined Transport
DAF	delivered at frontier
DDP	Delivered Duty Paid
DC	Distribution Center
ECR	Efficient Consumer Response
ERP	Enterprise Resource Planning
EDI	Electronical Data Interchange
ETCS	European Train Control System
EVA	Economic Value Added
EXW	Ex Works'
FOB	Free On Board
ICC	International Chamber of Commerce
IT	Information Technology
I&C	Information and Communication
JIS	Just in Sequence
JIT	Just In Time
M&A	Mergers and Acquisitions
MRP	Material Requirements Planning
ODBC	Open Database Connectivity
OEM	Original Equipment Manufacturer
OPT	Optimized Production Technology
p.a.	per annum
p.c.	per capita
POS	Point Of Sale
UML	Unified Modeling Language
RDA	Resource Dependence Approach
RFID	Radio Frequency Identification
SC	Supply Chain
SCM	Supply Chain Management
SCP	Supply Chain Performance
SCOR	Supply Chain Operations Reference
SRM	Supplier Relationship Management
TCO	Total Cost of Ownership

TEU	Twenty-foot Equivalent Unit
VMI	Vendor Managed Inventory
WMS	Warehouse Management System

Sites in Simulation Study

GEN	Geneva
LAU	Lausanne
MON	Montey
MOR	Morges
NYO	Nyon
PAY	Payerne
PF SIO	platform Sion
SIO	Sion
SIE	Sierre
T DAI	Dailens Terminal
T HAE	Härkingen Terminal
VES	Vesenaz
VEV	Vevey
YVE	Yverdon

1 Integration of Combined Transport into Supply Chain

Concepts from a Performance Perspective: Need for Action

Combined transport (CT) is increasingly gaining the interest of policymakers, the general public, production and retailing companies as well as third party logistics providers (3PLs). As the combination of rail and road transport, CT is perceived as a feasible approach to deal with changing supply chain performance (SCP) requirements and the latest problems in road transport. Today, supply chain (SC) activities are evaluated not only according to cost, time and quality, but also performance requirements in terms of flexibility, reliability and sustainability. CT seems to be one alternative to unimodal road transport concepts to meet changing SCP requirements. However, CT underlies several inherent and market-related disadvantages. Additional transshipment processes and coordination activities usually require additional time and cost quotas. To reach an equivalent SCP the required time quotas must be gained by a targeted alignment of all upstream and downstream SC activities. This means that procurement, production and distribution concepts must be configured with regard to the CT integration.

The research objective of this thesis is the theory-guided development of practical guidance for the integration of CT into SC concepts. This overarching objective can be divided into three secondary objectives: (1) the identification and classification of shippers' requirements regarding transport concepts in general, (2) the identification of relevant elements, correlations and cause-and-effect relationships for the CT integration and (3) the development of specific recommendations on the instruments and measures supporting the integration. The following section concretises the problem description in the form of three research questions (section 1.1). The scientific-theoretical positioning and the resulting research design to answer these questions (section 1.2) as well as the thesis and research outline are introduced (section 1.3).

1.1 Problem Formulation and Research Questions

Problem Formulation

Recent SC concepts can be characterised by the attempt to reduce inventory and to simultaneously increase flexibility and reliability. SC concepts bind the production, pro-

curement and distribution processes of shippers, suppliers as well as the embedded and linking transport concepts.¹ 3PLs are increasingly integrated into the collaboratively synchronised value-adding processes.² These changes reflect the growing performance and value orientation of supply chain management (SCM), as expressed by the application of target systems that join key operative and strategic figures.

The material flow in SC concepts – especially in the last mile – is commonly accomplished by unimodal road transport concepts. Here, in practice the vision of cross-company process linking meets its boundaries. Restrictions such as infrastructure shortages, increasing oil and energy prices, protectionism and ongoing market consolidation decrease reliability and speed.

As a result, CT becomes a central interest of policymakers, the general public, shippers and transport actors. CT seems to be a promising solution to overcome the latest problems in unimodal road transport and the vulnerability of SC concepts. CT combines the advantages of rail transport. It combines the advantages of cost efficiency of high transport volumes and weights with the low emission rates of rail transport with the high flexibility, continuous driver accompaniment and low costs over short distances of road transport. Next to usage for international or hinterland transport, there are first examples of the cost, time and quality neutral CT integration for short distance inland transport over transport distances below 100 km.³

For instance, in Switzerland, several big retail companies have integrated CT into their SC concepts. The main haulage on rail is in some cases below 100 km. The companies prove that the CT concepts meet cost, time and quality performance requirements and even exceed the performance level of unimodal road transport in terms of reliability.⁴ The CT concept increases the reliability level of store supply. Furthermore, CT improves the level of sustainability, expressed by the level of different emission factors (e.g., carbon dioxide (CO₂), nitric oxide (NO_x), particles). Shippers promote these activities to improve their 'green images'.⁵ For instance, Lidl and Migros use specific containers with advertisements of their latest CT activities.

¹ cf. Bowersox et al. (2002), p. 12.

² See Fabbe-Costes et al. (2009); Shang (2009).

³ cf. Klaas-Wissing et al. (2010).

⁴ cf. Ibid.

⁵ In 2010, Coop bought the rail carrier *Railcare* to overcome the problems of process integration. cf. Railcare (2011).

Nevertheless, current literature and practice state that in most cases CT for inland and last mile transport is insufficient to meet recent SCP requirements.⁶ Experts state that the main task of CT actors is to strengthen shippers' trust in the performance of CT.⁷ The inherent disadvantages, especially the additional time quota caused by additional transshipment processes, the high coordination effort and the resulting high cost level are central aspects exacerbating a performance-oriented CT integration into SC concepts.

Transport concepts are central elements of SC concepts. They are embedded into the sub-concepts of procurement, production and distribution, connect SC actors and cover the 'last mile' distance to end customers. Therefore, they pass the performance characteristics of the entire SC to the end customer. Although transport actors connect all actors of the 'integrated' SC, they are often not integrated members themselves. This means that transport actors are usually not involved in SC planning activities, are not connected to IT systems and are often understood as the 'servants' to the procurement, production and distribution concepts.

The thesis in hand exploits this imperfection regarding the integration of CT into SC concepts. It is assumed that closing this 'integration gap' opens up time buffers and coordination flexibility, which allow the integration of CT while reaching the performance level of unimodal road transport. Therefore, a careful alignment of the SC and CT concepts is necessary.

To reach this target the thesis in hand suggests an innovative perspective on the integration problem. It is assumed that the adaptation of the SC concept, namely the sub-concepts of procurement, production and distribution, to the characteristics of a specific CT concept is necessary to reach the required integration of material and information flow processes. This comprehension corresponds to a complete renunciation of the understanding of the transport concept as a servant. Instead, the transport concepts are interpreted as a guiding criterion for SC configuration.

Research Gap

Approaching this practical motivated problem formulation from a theoretical perspective, it can be stated that no published empirical work has yet dealt with the integration of CT into SC. Neither the SC integration literature nor SCP management research have so far considered the meaning of transport concepts and actors for SCP. There is also a

⁶ For instance Rapptrans (2005), p. 44; Klotz (2011).
⁷ cf. section 2.2.3.1; Klotz (2011).

shortage of literature analysing the interdependencies between the transport and SC concepts. This thesis contributes to close this research gap. For this purpose, the terms '*supply chain concept*', '*combined transport concept*' and '*supply chain performance*' are defined to be the central constructs. The working definitions and links of the central constructs are visualised in Figure 1 - 1.

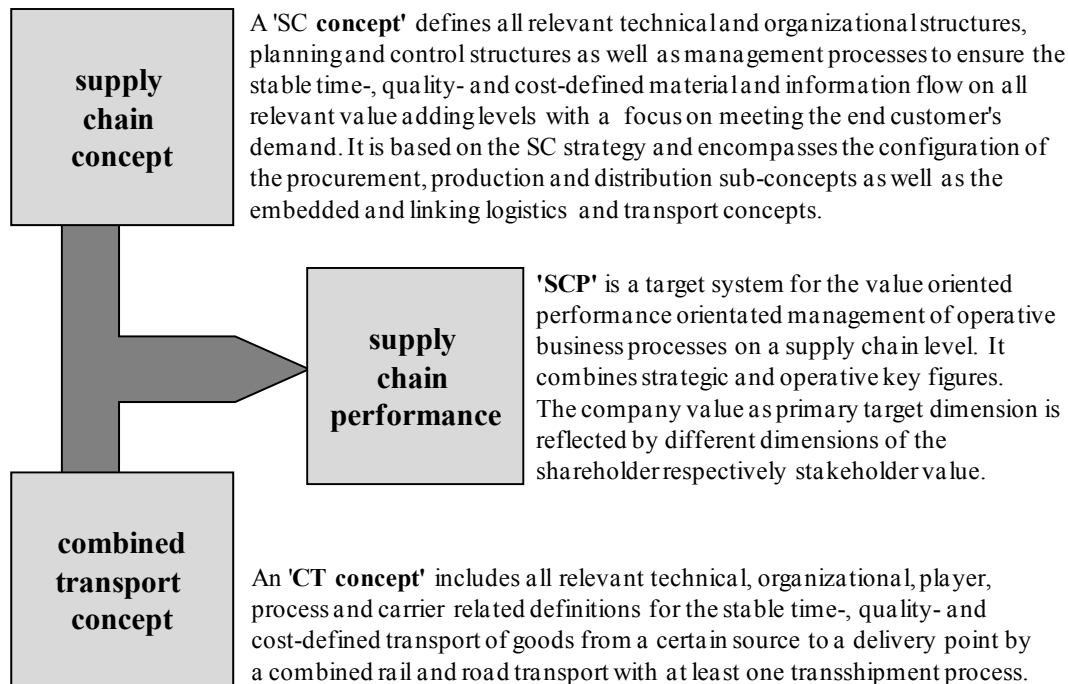


Figure 1 - 1: Working definitions of central constructs.⁸

A neutral and rational research perspective does justice to the high degree of novelty in both the practical and theoretical problem formulation. Thus, the focus is on the technical and organisational aspects of the CT integration problem. Further managerial aspects considering actor-specific perspectives are excluded. This reduces the complexity of the problem formulation and highlights the performance potential of CT integration into SC concepts.

The rough problem description proves the demand for further research. The following guiding research question is formulated to reflect the neutral research perspective:

Q₀: How can CT be integrated into SC concepts with regard to SCP?

Owing to the general character of the formulation, the research question is approached in three main steps.

⁸ Own illustration.

First, the structure and elements of SC concepts are examined. A typology of SC concepts is developed as well as an approach for the structured description of the SCP requirements regarding transport concepts.

Second, the meaning of process integration is highlighted. The SCP requirements of different procurement, production and distribution types in terms of the embedded and linking transport concepts are worked out and the impact on the integration of CT is discussed. For this purpose the procurement, production and distribution concepts are investigated in depth.

Third, the results are processed and enhanced for application in practice. A conceptual model to visualise the relations between the elements of SC and CT concepts is developed and the underlying cause-and-effect relationships are discussed. Finally, practical recommendations for the application on integrative measures and instruments to support CT integration are developed.

This threefold approach is reflected by three specific secondary research questions, aiming at different aspects of the guiding research question Q_0 .

Q₁: How can the requirements of SC concepts regarding transport concepts be described in accordance to SCP?

Q₂ Which interdependencies between the elements of the SC and CT concepts can be utilised for the successful integration of the material and information flow processes of shippers and CT actors?

Q₃ What practical recommendations can be derived for integrative measures and instruments to support CT integration with regard to SCP?

To understand how these research questions are approached in terms of research methodology and process, a general understanding of the thesis' positioning in research theory and philosophy is necessary.

1.2 Scientific-Theoretical Positioning and Research Design

The postulated research questions address different aspects of the same research problem. Thus, it is sensible to complement this rather general understanding by the scientific-theoretical positioning to support the choice of an appropriate research methodology.

Scientific-Theoretical Positioning

The thesis follows the principles of Punch (2005) and Saunders et al. (2007) by interpreting organisations as complex, open, social systems. Companies are influenced by a multiplicity of transformations.⁹ Following the considerations of Ulrich & Krieg (1974), organisations are assumed to be not completely controllable. From this perspective, business management is understood as applied science. The term '*applied*' means that the available theoretical knowledge is referred for application to the practice problem. To gain empiric knowledge is the pragmatic research objective. This objective aims not to test general theories and to explain reality, but to develop rules and models to create new realities.¹⁰

Ulrich (1995) distinguished between a theoretical and an applied research understanding.¹¹ In an applied research understanding, the problem formulation results from practice rather than from research. The problem formulation in the thesis in hand is identified in the SCM and CT practice. Ulrich (1995) claimed that in applied research understanding knowledge generation is rather inductive, whereas in theoretical research understanding it is deductive. The integration of CT into SC concepts seizes a complex and, up to now, practically and scientifically inadequately discussed problem formulation derived from economic practice. Recently, there has been no suitable approach for performance-oriented CT integration into SC concepts in practice. Thus, a purely inductive approach is insufficient for knowledge generation. There is no sustainable theoretical foundation for performance-oriented SC integration, either. Thus, a purely deductive approach for knowledge generation is insufficient, too. Hence, in the thesis in hand a combined inductive-deductive approach is applied. It is enhanced by a model-oriented simulative approach.¹² This supports the validation and improvement of the deductive results and supports the discovery of working relationships and principles.¹³

According to Ulrich (1995), the aim of applied research is to identify typical problems and to develop and test recommendations for a system's design rather than theory development.¹⁴ The thesis in hand aims at theoretical and practical research objectives. The theoretical research objective is the challenge to deductively identify and analyse

⁹ cf. Punch (2005), pp. 25; Saunders et al. (2007), pp. 136.

¹⁰ cf. Ulrich (1981), p. 168; {Ulrich, 1995 #976, pp. 165.

¹¹ cf. {Ulrich, 1995 #976}, pp. 165.

¹² cf. Axelrod (1997a) defined simulation as a 'third way of doing science' (Axelrod (1997a), p. 24). Simulations start with a set of explicit assumptions (as deduction does), but do not prove theorems. It generates data that can be analyzed inductively.

¹³ cf. Axelrod (2005); p. 4.

¹⁴ cf. Ulrich (1995).

the relevant cause-and-effect relationships between the elements of SC and CT concepts for the performance-oriented CT integration using suitable theoretical approaches. Furthermore, configuration theory is transferred to the new application field of CT. The results will be compressed into specific design advice and practical recommendations for the performance-oriented integration of CT into SC concepts. For this purpose, the conceptual research framework is the major instrument.

In a theoretical research understanding the quality criterion is the universality of the findings. In applied research, the criteria are the reliability and applicability of the developed methods and rules for practical problems. Thus, the thesis in hand aims at the closeness of the developed conceptual model and, furthermore, at the applicability of the developed recommendations and their relevancy to the SCM practice. Table 1 – 1 summarises the considerations of the scientific-theoretical positioning.

	theoretical research understanding	applied research understanding	characteristics of this research
problem formulation	in research	in practice	in the practice of SCM and CT
knowledge generation	deductive	inductive	deductive model oriented-simulative** inductive
research target	theory development / testing: explanation of existing reality	identification of typical problems and testing design suggestions	development of practical recommendation on the performance-oriented integration of CT into SC concepts
research criteria	universality	reliability and applicability of methods and rules; practical problem solving power	closeness of developed conceptual model; applicability of recommendations; relevancy to SCM practice

Table 1 - 1: Scientific-theoretical positioning of the thesis in hand.¹⁵

The research design is a consequence of the scientific-theoretical positioning.

Research Design

The thesis in hand applies a combined inductive-deductive approach enhanced by a model-oriented simulative research approach. Within this framework, statements are deductively gained based on configuration theory and are complemented by empirical knowledge.¹⁶

¹⁵ cf. Ibid.

¹⁶ The research design can be described as the summary of research, including data gathering, data analysis and interpretation. cf. Punch (2005), pp. 22, 133; Sarantakos (2004), p.14. The research design contains the positioning within the empirical research and acts as link between research questions as well as data basis. cf. Saunders et al. (2007), pp. 5. The design process includes relevant research strategic and methodological decisions: research philosophy, research approach, research strategy, chronological direction as well as the data gathering methods cf. Sarantakos (2004), p. 23.

The research design can be divided into two main steps:

- (1) The first step contains the theory-guided development of a conceptual research framework and of propositions for the performance-oriented integration of CT into SC concepts.

The data basis for the deductive part of the research process is the preconception of the research problem developed in literature reviews, explorative interviews and explorative case studies in the fields of (a) CT, (b) SC integration, (c) SCP and (d) SCM. The conceptual research framework visualises the main argumentation line of the thesis.¹⁷ The framework includes the preliminary understanding (preconception) of the research problem and reflects both the practical and theoretical perspectives of the research problem.¹⁸ It serves as an explanatory model and as an orientation of the practical problem solution. The framework characterises reasons, designs and effects within the given problem formulation. It connects the important constructs and shows the visualisation.¹⁹

- (2) The second step is the simulation study for the inductive specification of deduced propositions and for the validation of the conceptual research framework.

The data basis for the inductive part of the research process is the simulation model based on empirical data on a Swiss retailer's distribution network. The simulation study analyses the effect of CT integration a distribution network with two distribution centres (DCs) and eleven stores. A discrete event-oriented material flow simulation shows the performance effect in comparison with unimodal road transport. Furthermore, the cause-and-effect relationships between the elements of the SC concept and the CT concept are analysed.

1.3 Research Process and Thesis Outline

Based on the research questions and the scientific-theoretical positioning, the research process and thesis outline are presented.

The research process reflects the tight connection of research and practice in application-oriented research.²⁰ In the first step, the practical research problem of CT integration into SC concepts is described comprehensively. Theoretical approaches from adjacent research fields, such as SC cooperation research, are reviewed for their applicabil-

¹⁷ cf. Wolf (2000), p. 37; Raffée (1989), pp. 37; Macharzina et al. (1991), p. 27.

¹⁸ cf. Ulrich (1981); Wolf (2008).

¹⁹ cf. Kubicek (1977), pp. 37; Wolf (2008), p. 3, 27.

²⁰ cf. Ulrich (1995), pp. 166.

ity. These theoretical solutions are analysed and a sophisticated model of CT integration, evaluation criteria and design recommendations presented. Finally, the design recommendations are validated and enhanced by means of a simulation approach.

The thesis is structured into six main parts. After this general introduction, the second chapter concretises the problem formulation and discusses different theoretical approaches to support the problem solving. First, the practical problem formulation of SC integration is analysed in detail (section 2.1). Second, the problem formulation is complemented with insights from specific fields of SCM and transport research. The specific inherent problems of CT are pointed out and are interpreted with regard to the integration into SC concepts and to SCP requirements (section 2.2). SCP is introduced as a system of objectives for the value- and finance-oriented management of SCs (section 2.3). Based on this compilation of challenges, theoretical explanation approaches suitable for the given problem formulation are introduced (section 2.4). Namely, the suitability of contingency theory for the integration of CT into SC concepts is shown. This theoretical approach supports the explanation of cause-and-effect relationships between the SC concepts' elements and the CT concept elements influencing SCP (section 2.4).

The third chapter addresses the meaning of a CT concept as an element of a SC concept. It clarifies the position and meaning of the CT concept on SCP. Therefore, the relationship between the procurement, production and distribution concepts and the embedded and linking transport concept is worked out. In particular, the relevant cause-and-effect relationships between the elements of the sub-concepts and the elements of the CT concept are identified. Initially, the third chapter analyses the construct of SC concepts as the operationalisation and implementation of a specific SC strategy (section 3.1). For the precise description of the SCP requirements regarding transport concepts a structured description framework with seven performance dimensions is developed (section 3.2). Based on this classification, the SC sub-concepts, namely procurement, production and distribution, concepts are analysed regarding their requirements for the embedded and linking transport concepts (section 3.3). In particular, the meaning of the SC concept configuration on the integration of the CT concept is worked out (section 3.3). Finally, a typology for the CT concept and corresponding performance profiles are developed (section 3.4).

The fourth chapter aims at the development of a conceptual research framework and the development of propositions on the performance integrated integration of CT into SC concepts. The conceptual framework illustrates the relevant interdependencies between the elements of the SC concepts, the CT concepts as well as integrative measures and

instruments with regard to SCP. In a first step, the main research idea is developed on the basis of the previous considerations. The section results in the description of the main proposition for the thesis in hand (section 4.1). The conceptual research framework builds on these considerations and follows the argumentation line of the configuration theory (section 4.2). In a step-wise approach, the central constructs of the research problem are segmented into middle range constructs as well as manifest and observable variables. The basic relationships between the main constructs and variables are summarised in first, rather general propositions. These propositions are specified in section 4.3. Here, the relevant cause-and-effect relationships between the elements of the SC and CT concepts as well as integrative measures and instruments are discussed in depth.

The fifth chapter aims at the specification and validation of the chosen aspects of the conceptual model by means of a simulation study. Therefore, the problem formulation is specified through the analysis of a lean SC concept and a combined CT concept with regular line trains.²¹ First, the research design of the simulation study is introduced. The suitability of the simulation method for the given research problem, central quality criteria and restrictions of the chosen methodology are discussed. Furthermore, the choice of a specific simulation approach and a simulation tool are discussed (section 5.1). Second, the development of the simulation model of the distribution network of a Swiss retailer is described (section 5.2). This includes the introduction of the simulation-specific problem and target definition (section 5.3), of the data gathering and editing process (section 5.4), the development, validation and verification of the simulation model (section 5.5), the development of the experimental plan and the setup of experiments (section 5.6) and the discussion of simulation runs and results (section 5.7).

The sixth section highlights the central managerial (section 6.1) and practical implications (section 6.2) of the thesis in hand. Additionally, the section discusses the limitations of the findings and works out future research perspectives (section 6.3).

Figure 1 – 2 gives an overview of the application-oriented research process and thesis outline.²²

²¹ The different CT types are introduced in section 3.4.
²² Based on Ulrich (1995), p. 167.

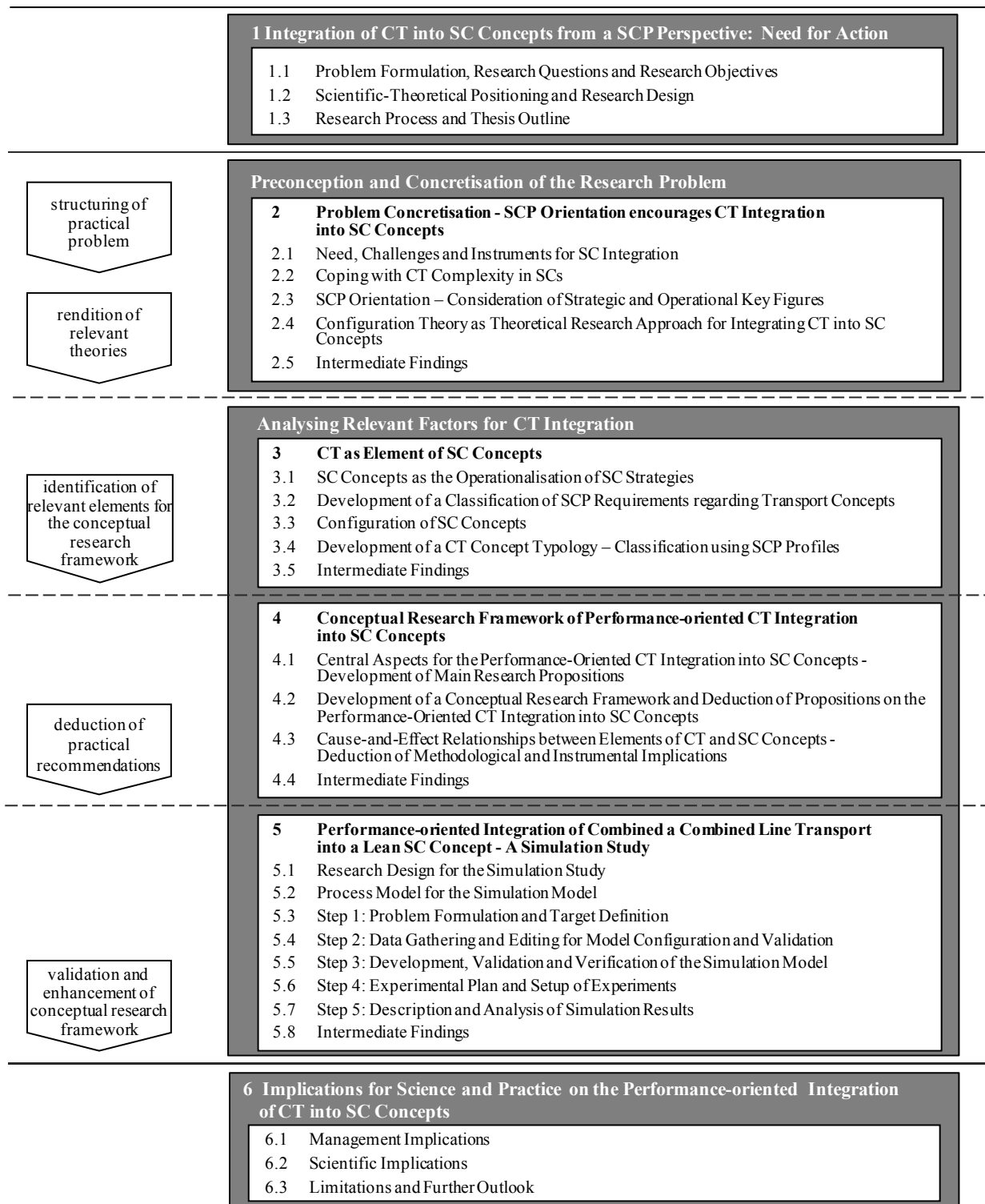


Figure 1 - 2: Application-oriented research process and thesis outline.²³

²³

Own illustration in accordance with Ulrich (1995), p. 176.

2 Problem Concretisation - SCP Orientation Encourages the Integration of CT into SC Concepts

The second chapter concretises the problem formulation and discusses different theoretical approaches to support the problem solving. First, the practical problem formulation of SC integration is analysed in detail (section 2.1). Second, the problem formulation is complemented with insights from specific fields of SCM and transport research. The specific inherent problems of CT are pointed out and are interpreted with regard to the integration into SC concepts and to SCP requirements (section 2.2). SCP is introduced as a system of objectives for the value- and finance-oriented management of SCs (section 2.3). Based on this compilation of challenges, theoretical explanation approaches suitable for the given problem formulation are introduced (section 2.4). Namely, the suitability of contingency theory for the integration of CT into SC concepts is shown. This theoretical approach supports the explanation of cause-and-effect relationships between the SC concepts' elements and the CT concept elements influencing SCP (section 2.4). The main results of the chapter are then summarised in the form of intermediate findings (section 2.5).

2.1 Needs, Challenges and Instruments for SC Integration

This section points out the needs, the challenges and instruments of SC integration. The research stream on SC integration usually focuses on the integration of shippers (retailers and manufacturing companies) in buyer–supplier relationships. Lately, research activities have focused on the integration of 3PLs, too.¹ Although, there are no specific publications on the integration of (combined) transport actors into SCs, the research stream of SC integration is the basis for the further considerations of the CT integration into SC concepts. In a first step, the framework conditions, which force companies to closer integrate material and information flows with their SC partners, are discussed. Furthermore, the internal and external challenges of the integration are identified and analyzed with regard to the problem of integration of CT into SC concepts. Finally, central measures and instruments to reach SC integration are introduced.

¹ e.g., Fabbe-Costes et al. (2009).

2.1.1 Need for SC Integration

Changing framework conditions force companies to increasingly focus their activities on end customers' needs. In times of decreasing customer loyalty, customers choose the product that best fits their needs in terms of cost, availability and customisation. Thus, *customer orientation* is perceived as the key factor for competition among SCs. To create a customer-oriented SC a close cross-company integration of material and information flow processes is necessary.

Framework Conditions Require the Close Integration of Material and Information Flow Processes

A quantity of framework conditions exacerbates reaching customer orientation for companies and SCs. These framework conditions increase the performance requirements of SCs and thereby imply a close cross-company integration of material and information flows.

SCs have to deal with *various challenges*, such as the demand for individualised products, contracting product life cycles, shorter delivery times and high quality levels. A strong price competition among retailers implies low inventory levels and punishes out-of-stock situations. Retail and manufacturing companies promise availability, innovativeness, uniqueness and low prices to end customers. This encompasses the availability of seasonal, cooled, frozen and hazardous goods. These special products have specific requirements in terms of storage, handling and transport. For instance, groceries and pharmaceuticals must be consistently temperature-controlled and perishable goods require comparably short lead times.²

Society, policy and companies evaluate SC activities increasingly with regard to their *sustainability and environmental impact*. This means that not only the economic impact of an SC activity is taken into consideration.³ The orientation towards sustainability supports the stronger integration of material and information flow processes, since better planning and stronger bundling may reduce the waste of materials, transport capacities and thereby energy.

Safety and security activities claim to increase requirements in terms of tracking and

² cf. Anckar et al. (2002); Fernie (1995); Kent et al. (2001); Makinwa (2010).

³ A complete research stream has emerged for the topic 'sustainable SCM'. See for instance: Craig et al. (2008); Linton et al. (2007); Markley et al. (2007); Pagell et al. (2008); Pagell et al. (2009); Seuring et al. (2008a); Seuring et al. (2008b); Svensson (2007).

tracing systems and the interruption-free monitoring throughout the SC. Production characteristics as well as transport conditions must be tracked and the data stored. In particular, cross-company transport must do justice to security regulations.⁴ To do so, the transport actors need specific knowledge on the transported goods and rely on close information flow integration with the shipper and all other SC actors.

The *Internet* leads to further changes in the structure of the global flows of goods. Customers can receive information on the best quality, prices, competitive products and alternate brands anywhere and at any time.⁵ For instance, social networks and message boards spread positive and negative information and may cause a rapid image decline or promotion of a specific product, brand or company.⁶ The Internet opens up new sales channels.⁷ Not only books, clothing and electronics are sold via the Internet, but recently shops for pharmaceuticals, groceries and photographs are increasingly gaining customers' interests.⁸ Thus, transport units are growing smaller and more time-critical. This effect is called the '*cargo structure effect*'.⁹ Often this goes along with the end customer's claim to be well informed on recent shipment statuses. Thus, tracking and tracing systems are required to closer integrate the information flow.

Finally, there is an *ongoing internationalisation of production and sales activities*. On one hand, the reason for this development is the reduction of production and personnel costs by shifting manufacturing sites or outsourcing production and logistics processes. On the other hand, companies open up new markets, such as the so-called BRIC and Next 11 countries.¹⁰ Internationalisation leads to global transport and logistics networks, ensuring end customers are supplied with the demanded goods. The effect of this ongoing internationalisation is also-called the '*logistics effect*'.¹¹

⁴ For instance, transport from and to the US must send announcements to the destination 24 hours in advance.

⁵ For the meaning of the Internet on SCM see for instance, Lancioni et al. (2000).

⁶ cf. Peters (2010).

⁷ See, for instance, Gimenez et al. (2008); Gundlach et al. (2006)

⁸ In Switzerland, for instance, the two biggest retailers introduced online shops for groceries. See for instance: <http://www.coopathome.ch> and <http://www.migros.ch/de/online-shops.html>. See furthermore, Anckar et al. (2002), Baen (2001), Barua et al. (2000), Gundlach et al. (2006).

⁹ cf. Kille et al. (2008).

¹⁰ FinanceContent (2011). The terms go back on Jim O'Neill (Goldman Sachs). BRIC = Brazil, Russia, India and China. Next 11: Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippines, South Korea, Turkey and Vietnam.

¹¹ cf. Kille et al. (2008).

Consequences for the Configuration of SC Concepts

The presented framework conditions require a close cross-company integration of material and information flow processes. Namely the procurement, the production, the distribution and the embedded logistics and transport processes are designed to meet the growing SCP requirements. For instance, production processes are distributed worldwide, raw materials, supplies and components are sourced globally and multilevel distribution concepts are introduced to reach the required level of shelf availability by means of early morning and multiple deliveries.¹²

A quantity of standardised logistics and SC concepts improving SC integration is applied in practice in order to deal with operative challenges in a complex and dynamic SC environment. For example, Stölzle (1999) discussed the meaning of these concepts on the integration aspect.¹³ On the demand side, for instance the CPFR concept (collaborative planning, forecasting and replenishment), the VMI concept (vendor-managed inventory) and the ECR concept (efficient consumer response) can be applied. From a supply point of view, supplier and industry parks as well as just-in-time (JIT) and just-in-sequence (JIS) concepts provide the framework for the integration of material and information flows.

What is SC Integration?

The term '*SC integration*' means the integration of material and information flows between SC actors. According to Cooper et al. (1997), *SC integration activities* encompass:¹⁴

- *SC structure integration* (SC relationships, inter-organisational business units)¹⁵
- *SC process integration* (business processes, material and information flow process integration)¹⁶ and
- *SC management integration* (network culture, leadership, incentive schemes, SC controlling).¹⁷

¹² cf. Geir et al. (2006); Gerbens-Leenes et al. (2003); Henning et al. (2009); Kempainen et al. (2003); Linton et al. (2007); McKinnon (2009); Mortensen et al. (2008); Webb (1994).

¹³ cf. Stölzle (1999), pp. 147.

¹⁴ In accordance with the three main elements and key decisions of the SC conception.

¹⁵ SC structure integration deals with the development of SC relationships (e.g., trust building activities) and the introduction of cross-company organisational units (e.g., project teams). Cooper et al. (1997), pp. 70.

¹⁶ SC process integration means the cross-company integration of business processes. These efforts can span all value-adding levels, for example research and development, demand planning, disposition or capacity utilisation processes. Ibid., pp. 70.

A tight cross-company integration of material and information flow processes means that at the interfaces between different companies, time buffers are not required and information is not lost. The material flow processes are harmonised and synchronised between SC actors. Therefore, the production, transport and storage quantities are balanced and arrival and delivery frequencies, quantities and unit sizes are cooperatively planned. The controlling of sourcing, production and distribution processes is also accomplished cooperatively. This reduces, for instance, required warehouse capacities. So-called '*buffers*' gather production materials and goods for the next operation.¹⁸

An example of a tight integration of material and information flow processes is the JIT delivery concept, which can be typically found in the automotive industry.¹⁹ Here, the information flows of suppliers, buyers and usually carriers are tightly connected by common information systems or platforms. The original equipment manufacturer (OEM)²⁰ provides the supplier with forecasts on the planned production quantities and production program for a defined time horizon in advance. These forecasts are the basis for the suppliers' sourcing processes and capacity planning. On a daily basis, the OEM specifies and updates the demanded parts in a so-called '*delivery schedule*'.²¹ Therefore, standardised communication protocols are applied and usually used by all OEMs and suppliers.²² The supplier uses the delivery schedule to initiate its own production processes, often not more than 8 to 48 hours in advance. Here, a so-called '*pull control logic*' is applied. The material and information flow processes are '*synchronised*'. A frequent, regular line transport concept with low transport quantities connects suppliers and OEMs without warehousing processes.²³

This type of synchronisation of production processes between the OEM and upstream suppliers as well as the production processes and end customers' demands are also core aspects of the Toyota Production System. Harmonisation and levelling balance fluctuating customer orders. This means that production is not adapted to the orders

¹⁷ SCM integration means benefits for all involved SC members. Companies can access rare resources and new markets. They can share risks and reach synergy effects, e.g., developing new products and services, economies of scale and knowledge. Ibid., p. 70.

¹⁸ cf. Ihme (2006), p 11.

¹⁹ See, for instance, Aigbedo (2007); Nielsen et al. (1995).

²⁰ Original Equipment Manufacturer = 'A producer that provides a product to its customers, who proceed to modify or bundle it before distributing it to their customers.' Investorwords (2011).

²¹ cf. Ihme (2006), pp. 250; Jünemann (1989).

²² cf. Ihme (2006) pp. 169.

²³ For more details on control logics in production systems, see section 3.2.3.

on a daily basis, but rather that production quantities and programs are planned for some time in advance, for instance a week. This weekly program level harmonises customer orders and leads to a stable and continuous production flow.

The tight integration of material and information flow processes has several advantages.²⁴ Inventory levels can be kept low. Short-term changes can be realised because of the close coupling of the OEM's and suppliers' processes. High frequent JIT delivery concepts with small transport quantities serve as small inventory buffers. This combination of individualised products and short-term changes leads to a high level of customer orientation.

But the cross-company integration of material and information flow processes has several requirements and disadvantages. There must be a high level of trust among SC actors. These actors must allow the other insight into forecasts and planned production quantities. Hence, partners risk that this information is used opportunistically. In this case, trust and information sharing can mean economic disadvantages. The close coupling of material flow can lead to delivery disruptions to the end customer if there are problems in the upstream production or transport processes.²⁵

2.1.2 Central Elements and the Fields of SC Integration

SC configuration, coordination and cooperation can be understood as the basis of SC integration. The general agreement of SC actors to coordinate their connections and to determine the nodes within a SC network is the requirement for SC integration.

SC configuration comprises the configuration of material flows in the network of SC actors. It contains the definition of the focal company's position within the SC and the choice of strategic partners. *SC coordination* aims at the development of long-term and stable supplier relationships. These relationships allow the realisation of process, transaction, production and research and development cost savings. Furthermore, SC coordination activities aim at the increase of quality and service levels and the reduction of supplier risks. According to Lambert & Pohlen (2001), coordination activities can be distinguished according to the characteristics of the linked proc-

²⁴ See for instance Mentzer et al. (2001a); Min et al. (2007).

²⁵ For further details on vulnerability, see the following section.

esses.²⁶ They depend on the specific SC configuration.²⁷ *SC cooperation* activities depend on the qualitative and quantitative capability of SC partners. The intensity of cooperation activities must be distinguished according to the meaning of the partners as well as the involved processes.²⁸ *SC process integration* involves the cross-company integration of business processes at all value-adding levels.

The terms of SC configuration, coordination, cooperation and integration are tightly connected. It can be summarised that these constructs are the basis to implement a cross-company SC strategy and to improve SCP.²⁹ SCP emerged to solve the conflict between the performance-orientation of operative business processes at the SC level³⁰ and the primary target of company value increase. It can be reflected by different dimensions of shareholder value.³¹ The meaning of SCP orientation is analysed in depth in section 2.3.

2.1.3 Normative, Operative and Strategic Challenges of SC Integration

This section introduces the general challenges of SC integration. Also the problem of CT integration into CT into SC concepts is considered on three different levels.

2.1.3.1 Overview on SC Integration Challenges

Karrer (2006) identified three main impediments that prevent the systematic and performance-oriented integration of CT into SC concepts:³²

- (1) *Main objectives of the integrated SC* are not valid for all SC actors (normative challenge),

²⁶ cf. Lambert et al. (2001), p. 112 Managed' process links are critical for the focal company and thus, actively managed. 'Monitored' process links are important, but not critical and finally 'non-managed' process links. Here the focal company is not directly involved and thus, the managing effort is not justified. Furthermore, process links with non-actors of the SC can be distinguished. These are links where the SC is influenced by decisions or other SCs.

²⁷ cf. Rudberg et al. (2003), p. 36.

²⁸ cf. Trumfheller et al. (2004), p. 81.

²⁹ See for instance Duffy et al. (2006), pp. 57; Hsu et al. (2007), p. 296; Vereecke et al. (2006), p. 1176; Weber et al. (2000), p. 54; Fabbe-Costes et al. (2008).

³⁰ cf. Karrer (2006), p. 213.

³¹ cf. Ibid., p. 213. The introduction of the SCP indicates that SC actors do not only concentrate on the content-related arrangement and adjustment of SC elements according to the corporate requirements, but on the measurability and controllability of the SCP (Sennheiser et al. (2008), p. 1). SCP can be concretised by the characteristics of efficiency and effectiveness orientation, multidimensionality and the future and potential orientation (Stölzle et al. (2004b), p. 125).

³² cf. Karrer (2006), p. 2.

- (2) Operational objectives and *challenges of shippers and CT actors* significantly differ because of the different core businesses in either production, retail or service delivery (operative challenge),³³
- (3) SC and CT actors focus their activities on their *own company value growth* (strategic challenge).

These impediments are reflected by the differing operative and strategic target systems and key figures to measure the target achievement of processes, people, business units, divisions or companies.³⁴ According to Wilke (2001), these impediments lead to so-called control gaps.³⁵ These gaps represent the general discussion on control scepticism on the control of complex social systems and thus, of SC processes.

To develop practical recommendations on the integration of CT into SC concepts the introduced challenges must be taken into deeper consideration. Thus, the following section analyses in depth the three main challenges of SC integration and interprets them in terms of CT integration.

2.1.3.2 Challenge 1: Main Objectives of Integrated SCs – Problems of SCM Conception

The first challenge of the performance-oriented integration of CT into SC concepts is the unsophisticated design of SCM conception. As a result, the corporate system of objectives of SC actors does not usually correspond to the main objectives of SCM.

According to Mentzer et al. (2001a), SCs can be defined as '*[...] set of three or more entities (organisations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer*' (Mentzer et al. (2001a), p. 1). The SCM conception can accordingly be characterised by three main issues:

³³ In the given context, 3PLs are understood in a double role. On one hand, the central CT actors (e.g., operators, carriers, tractioners) are 3PLs. On the other hand, 3PLs can act as shipping companies and principals for intermodal transport concepts. Thus, in the applied understanding the term 'shippers' includes production and retail companies as well as 3PLs.

³⁴ cf. Sennheiser et al. (2008), pp. 186; Schönsleben (2002).

³⁵ cf. Wilke (2001), pp. 1.

(1) SCM must be understood as a system approach. This means that a SC must be considered as one unit and thus, managed as a whole.

The consideration of a SC as a system is confirmed by several authors.³⁶ In this interpretation, companies can be understood as system elements and with trade-off relationships.³⁷ For instance, in Wohlgemuth (2002) showed that the performance potential in a SC can only be disclosed when a whole value-adding network and not only dyadic partners and bilateral relationships are considered.³⁸ For the performance-oriented integration of CT into SC concepts this means that all CT actors must be included in the SCM and in planning activities.

(2) SCM is a strategic as well as a cooperative approach that spends resources for synchronising and converging activities between SC members.

This statement highlights the different aspects of SCM. First, it is assumed to be strategic. This means that SCM has a long-term character and it is understood as an instrument to reach competitiveness. Second, SCM is supposed to be cooperative. Thus, SC actors cooperatively work together to synchronise their material and information flow processes. Third, the term '*converging*' implies that SC actors need a common target system.³⁹ Transferred to the given research problem, this means that the performance-oriented integration of CT into SC concepts has strategic meaning for the involved actors. Furthermore, the integration can only be accomplished cooperatively with a common target system, which is valid for all SC actors.

(3) SCM addresses customer orientation. The authors point out that an individualised source of customer value must be established.

This statement highlights the SCM customer orientation.⁴⁰ As shown in the previous section, customer orientation is perceived as the key factor for competition among SCs. The integration of material and information flow processes is pointed out as the prerequisite for customer orientation. Customer orientation is expressed by the meeting of end customers' demands, for instance, regarding high delivery service, low costs and individualised products, despite obstructive framework conditions, such as infrastructure shortages or political regulations. For the integration of CT into SC concepts this means that CT actors have to align their activities towards the end cus-

³⁶ cf. Mentzer et al. (2001b), p. 1.

³⁷ cf. Karrer (2006), p. 86.

³⁸ cf. Wohlgemuth (2002).

³⁹ cf. Mentzer et al. (2001b), p. 7.

⁴⁰ cf. Min et al. (2007).

tomor orientation, too.

Although the importance of SCM in practice has been proved by several surveys,⁴¹ the initial ideas of the SCM concept often conflict with the applied systems of objectives. Furthermore, recent management approaches are not sufficient to deal with cross-company control problems. Hierarchical control approaches, differentiating between lead and operative instances, cannot be applied within a SC context.⁴² Thus, the interests of multiple stakeholders (e.g., shippers, terminal operators, CT operators, tractioners, carriers and end customers) have to be adjusted and conflicts of interests have to be considered. To realise advantages for all stakeholders, appropriate measures and instruments have to be applied. Whereas key figures of strategic management are appropriate for a post evaluation of functional divisions, process-oriented and cross-company key figures (such as lead times, capacity utilisation, adherence to schedules and inventory levels) are not included in strategic, financial key figure portfolios.

Target System of SCM

There are five main SCM objectives. According to Gladen (2003), formal and content objectives of SCM are distinguished. The increase in end customers' benefits leads to an increase in the value of the SC. In order to increase the SC's value, companies attempt to decrease costs, realise time advantages and increase quality. Figure 2 -1 provides an overview of the linking between formal and content targets and provides examples for associated target dimensions.

⁴¹ See, for instance, Accenture et al. (2003), Straube et al. (2008).
⁴² cf. Wildemann (2004b), Wildemann (2000), p. 8.

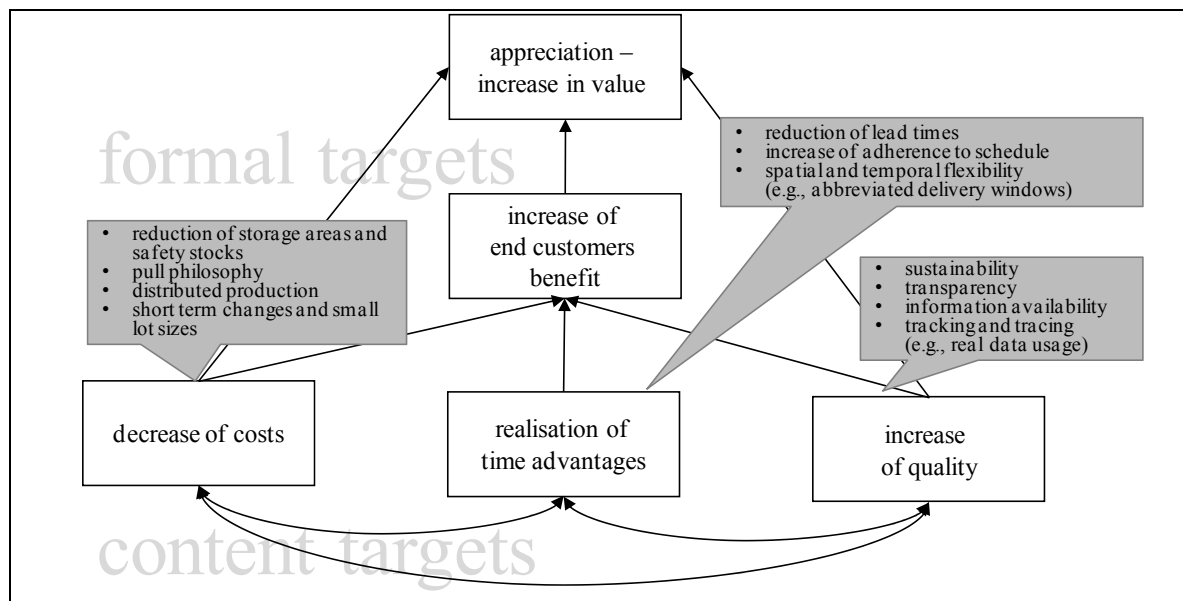


Figure 2 - 1: Linking of formal and content targets of SCM.⁴³

End customer orientation can be understood as the primary target of SCM. All other target dimensions can be derived from this overarching target.⁴⁴ End customers' benefits can be substantiated by the classical service objectives of logistics.⁴⁵ According to Pfohl (2010), these are the delivery time, delivery availability, delivery quality and delivery flexibility.⁴⁶ However, in SCM end customer benefit means the consequent orientation of all processes towards the end customers' needs.⁴⁷ The information about the specific state or status of the delivery can be interpreted as a benefit to the end customer, too.

With the increasing value orientation of management, value orientation principles are also integrated into the SCM conception.⁴⁸ This new way of thinking means that all value-adding activities in a SC must be aligned with the long-term target of value increase. Within a single company, this means that in SCM, the cause-and-effect relationship between often operative value drivers and corporate financial performance must be analysed.⁴⁹ Taking a cross-company perspective, value orientation means that the partial interests of single SC actors must be shifted towards the long-term maximisation of SC value. However, this target usually conflicts with the interests of

⁴³ With adaptations and enhancements, according to Ibid., p. 31.

⁴⁴ cf. Stefansson et al. (2000), p. 258; Heusler (2004), p. 20.

⁴⁵ cf. Pfohl (2010), pp. 36.

⁴⁶ cf. Ibid., pp. 43.

⁴⁷ cf. La Londe et al. (1994), pp. 46.

⁴⁸ For a value increase in SCM, see Otto et al. (2002), pp. 126; Möller (2003); Neher (2003); Hofmann et al. (2004).

⁴⁹ cf. Weber et al. (2001).

individual SC actors, who wish to increase their own values.⁵⁰

The decrease in costs, realisation of time advantages and increase in quality are the content targets leading to the formal targets of end customer orientation and value increase in the SC.

The idea of decreasing costs transfers the logistics principle of the '*total cost of ownership*'⁵¹ to SCM. SCM cost categories include the costs of the SC structure (e.g., fleet and warehouse costs, locations of production facilities, warehouses and transshipment points), SC processes (e.g., transport, handling, storage costs) as well as SC floating assets (e.g., inventory costs, introduction of pull philosophy, safety stocks).⁵² There are several cost accounting techniques to monitor SC costs.⁵³

The realisation of time advantages assumes that the end customer is generally interested in the fast delivery of the demanded product. Thus, the reduction in lead times and increase in adherence to schedules are sought. Different time spans are of special interest. The so-called '*time to market*' means the time between product development and market introduction. The '*delivery time*' means the time from order to delivery.⁵⁴ There are further time measures, such as '*time to react*' to describe the duration required to react to short-term changes or to adapt the SC after disturbances.⁵⁵ For instance, the so-called '*Quick Response*' concept gives the time dimension a specific meaning.⁵⁶

The increase in quality means both the product and process quality. Benchmark is the subjective quality evaluation of the end customer.⁵⁷ For instance, the Total Quality Management approach focuses on a cross-company establishment of quality standards for process planning and operation.⁵⁸ Recently, the quality dimension has experienced an enhancement. Sustainability aspects are integrated into the quality understanding. Furthermore, knowledge management is encompassed, since the bundling of knowledge and resources can lead to learning effects in the SC.⁵⁹

⁵⁰ cf. Karrer (2006), pp. 54.

⁵¹ cf. Pföhl (2010), pp. 30.

⁵² cf. for instance Christopher (2005b), pp. 80, Bowersox et al. (1999), Callioni et al. (2005), pp. 135.

⁵³ For process cost accounting, transaction cost accounting or the total cost approach as the developments of accounting in logistics see Bowersox et al. (1999), pp. 91, Weber (2002), pp. 45.

⁵⁴ cf. Christopher (2005a), p. 158.

⁵⁵ Background of the problem fields of complexity, intransparency and dynamics in SCs see Stölzle et al. (2001), pp. 75; Karrer (2006), pp. 54.

⁵⁶ The quick response concept interprets responsiveness, flexibility, the shortening of process times and real-time control as the main SCM target dimensions. For details see section 3.3.3.

⁵⁷ cf. Pföhl (2006), pp. 260.

⁵⁸ See Iakovou et al. (2008); Linton et al. (2007); Simatupang et al. (2002); Seuring et al. (2008b); Taplin et al. (2006);

⁵⁹ cf. Galgenmüller et al. (2004), pp. 84.

There are difficulties in the operationalisation of the introduced target dimensions. Additionally, mutual interdependencies between the objectives must be taken into consideration.⁶⁰ Owing to the number of SC actors – each of them with its own target systems and key figures – these interdependencies cannot be comprehensively modelled.⁶¹ However, the consideration of the different operative challenges of SC actors provides first insights into the conflicting goals in a SC including CT.

2.1.3.3 Challenge 2: Differing Operative Objectives and Problems of Shippers and CT Actors

There are multiple actors and operative challenges in one SC. However, between shippers and CT actors these challenges distinctively differ. Usually each SC actor focuses on his or her own field of operation and core competencies, although often the operative challenges have cross-divisional and cross-company characteristics. Nevertheless, the understanding of other SC actors' challenges and needs is usually limited. The integration of material and information flow processes requires encompassing knowledge on the operative challenges of all other actors.

In a first step, the different operative challenges of manufacturing, retail and transport actors are briefly discussed. Figure 2 - 2 gives an example of a SC including different modes of transportation. Exemplarily the figure provides an overview of the current operative challenges and focuses of different SC actors.

⁶⁰ cf. Karrer (2006), p. 22; Pfohl et al. (1997), pp. 88.

⁶¹ cf. Heusler (2004), p. 20, Karrer (2006), p. 22; Pfohl et al. (1997), pp. 89.

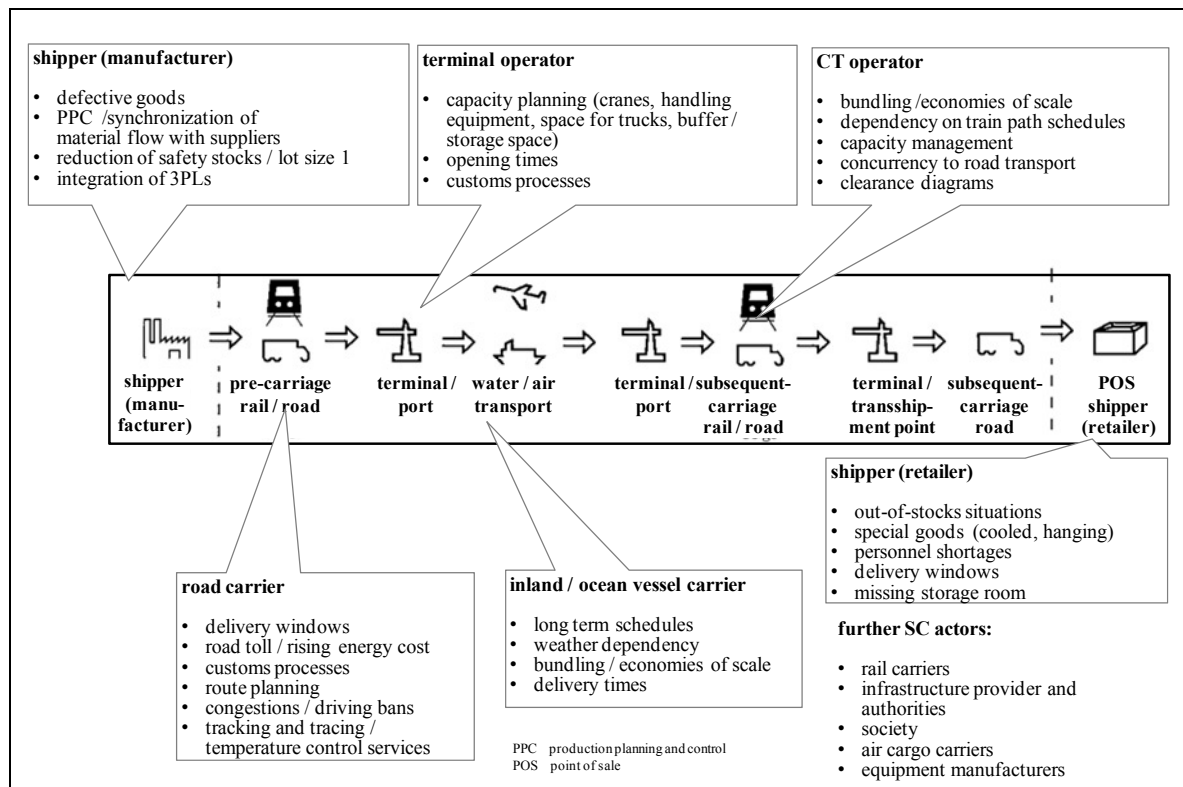


Figure 2 - 2: Differences in the operative challenges of selected SC actors.⁶²

SC managers of *retailers and manufacturers* aim to connect and synchronise the processes from the supplier's supplier to the customer's customer.⁶³ They try to connect the processes of the retail, service and producing companies from various industries. Each affected business unit deals with specific questions and sub-problems.⁶⁴

Manufacturers usually focus on the optimisation of quality and the resource efficiency of the production and assembly processes. Therefore, one central aspect is production planning and control (PPC).⁶⁵ For instance, the automotive industry claims PPC (next to the car assembly) is its core competency. According to the type of produced goods, manufacturers focus on either the realisation of economies of scale (reducing the marginal costs of mass production) or economies of scope (bundling effects through the common production of more than two products). They focus on the reduction of safety stocks, the utilisation of capacities (of machines, robots

⁶² Own illustration.

⁶³ See Cooper et al. (1997), p. 173.

⁶⁴ For instance, these operative challenges include supplier choice and supplier management, PPC, purchase prices, forecasting, marketing, customer management, shelf-availability and personnel effort.

⁶⁵ For further details on the tasks and objectives of PPC, see section 3.2.3.

etc.) and the acceleration of production, transport and logistics processes at a high quality level. This quality includes product quality, defective goods and adherence to schedules.⁶⁶

Retail faces the challenge of balancing assortment width,⁶⁷ marketing initiatives, fluctuating demand, missing storage room and personnel shortages because of low margins.⁶⁸ *Store management* focuses on optimal shelf availability, shelf space and the short replacement times accomplished by early morning and multiple deliveries.⁶⁹ The upstream DCs ensure stable and customised store delivery. Here, the focus is on efficient storage and order-picking systems as well as the provision and planning of the distribution transport and logistics processes.⁷⁰

The *3PLs and carriers* are influenced by the service character of transport and logistics.⁷¹ The main challenge is the immateriality of the service and the need to integrate the external factor. The customer of the logistics or transport service is the so-called external factor. This means that the performance of a service provider depends on the customer since the customer's behaviour, for instance at a good's provision, cannot be predicted.⁷² More and more 3PLs are integrated into the value-adding processes of shippers. For instance, 3PLs accomplish simple preparing production processes or value-adding processes, such as order picking and labelling.⁷³

Transport carriers must provide sufficient transport capacities and must economically utilise these.⁷⁴ *Road carriers* focus on the utilisation of transport capacities and the adherence to schedule dates and delivery windows for the delivery and collection of goods. Congestions exacerbate the punctual delivery of transported goods. The realisation of bundling effects and paired transport by appropriate route planning is essential in order to overcome the high level of fixed costs.⁷⁵ Further operative challenges include small delivery windows and rising transport costs because of tolls and energy costs. Increasingly road carriers apply the latest information and communication (I&C) systems, data loggers and temperature and state sensors to reduce transport

⁶⁶ cf. Bessant et al. (1994); Gupta (1995); Kaijie et al. (2007); Lo et al. (2009); Sroufe et al. (2008); Stanley et al. (2001).

⁶⁷ For instance, hanging goods (clothes), cooled, frozen, perishable and hazardous goods.

⁶⁸ See, for instance, Credite-Suisse (2007), Gudehus (2005), p. 950; Kotzab (1997).

⁶⁹ cf. Almehdawe et al. (2010); Baen (2001); Bretthauer et al. (2005)

⁷⁰ See for instance Gudehus (2005), pp. 968.

⁷¹ For details on the service character of transportation processes see Bendul (2009); Corsten et al. (1992), pp. 181.

⁷² For a discussion of the meaning of the service character of CT see section 2.2.2.5.

⁷³ For the scope of services provided by 3PLs see, for instance, Sheffi (1990); Forslund (2009); Carbone et al. (2005); Jayaram et al. (2011).

⁷⁴ cf. Bendul (2009).

⁷⁵ cf. Corsten et al. (1992); Stuhlmann (2000).

damages and loss, to increase transparency and to meet the information demand of shipments' recipients.⁷⁶ Furthermore, political regulations, such as emissions regulations, driving bans (for instance night, weekend and product driving bans), restrictive driving times and cabotage regulation influence road carriers' target systems.⁷⁷

Rail carriers as well as *CT operators* depend on the realisation of bundling and scheduling effects to deal with the high fixed cost level caused by specific investments. The availability and adherence of train paths, clearance profiles,⁷⁸ handling material and personnel are further challenges for CT actors. In particular, political aspects such as the infrastructure building as well as the dominance of passenger transport over freight transport (for instance, in Switzerland)⁷⁹ and regulation regarding noise emissions are central influencing parameters.⁸⁰

Inland or ocean vessel carriers operate on long-term schedules and depend on bundling effects as well as the realisation of economies of scale. The main advantage is the high transport volume and thus, the comparably low costs per unit and distance.⁸¹ Specific challenges are the comparable low speed, a strong weather dependency and for inland vessels the restricted inland water network.⁸² Infrastructure shortages in the European hinterland and the utilised capacities in ports can unexpectedly delay the delivery of goods. Lately, ocean vessel carriers are endangered off the East African coast because of pirate attacks.⁸³

Terminal operators respectively seaports are characterised by their locations and types. However, both inland and marine terminals focus on the capacity utilisation of investment-intensive handling equipment, such as cranes, reachstackers, waiting and storage spaces.⁸⁴ Increasingly, the offering of additional value-adding services, such as long-term storage, is central. At country borders as well as marine sites, short customs processes and fast transfers to the hinterland transport processes are the central evaluation factors for customers to choose ports and terminals.⁸⁵ Before the global

⁷⁶ For technology usage in transport concepts see Skorna et al. (2009); Grimm et al. (2010).

⁷⁷ An encompassing discussion on the meaning of transport policy impact on SC and CT see section 2.2.3.2.

⁷⁸ A clearance profile is defined framework line characterised by the vertical across level of a driveway of roads and railways. For details see Thillmann (2006); N.N. (2004a); Siegmann (2011a).

⁷⁹ See Gehrken (2011).

⁸⁰ For details on the scope and impact of transport policy on transport concepts see section 2.2.3.2.

⁸¹ The Emma Maersk is the recently (July 2011) the biggest ocean vessel. In sum 14.500 20' container TEU including 1000 containers for cooled goods can be loaded. For details see Mearsk (2011).

⁸² For problems in water transport see, for instance, N.N. (2011d); Jörgl (2011), N.N. (2011a).

⁸³ See Zamponi (2011); N.N. (2011c).

⁸⁴ cf. Seidelmann (1997); Seidelmann (2010).

⁸⁵ cf. Agersekov et al. (1983); Ballis et al. (2004); Wang et al. (2006)

economic crisis, many European inland and seaports and terminals had already reached their capacity limits. For instance, the port of Rotterdam, the Netherlands had lost transport volumes to smaller ports, such as Bremerhaven, Germany, since the customs processes and hinterland infrastructure connections allow shorter total lead times and higher adherence to schedules.⁸⁶ These examples show that the latest transshipment technologies and service orientation are central for terminal operators and ports.

Of these, several more actors indirectly influence SCP. They participate in the material flow processes themselves, but indirectly influence these *infrastructure providers, and authorities* provide the infrastructure framework for SC activities. The infrastructure providers are reliable for the enhancement and maintenance of the existing infrastructure of roads, railways, waterways and airports.⁸⁷

Authority and society further influence the enhancement of freight and people infrastructure. Examples are the reconstruction of the Stuttgart railway station⁸⁸ that was stopped by public protest and is still (August 2011) pending. The construction of the third runway at Frankfurt Airport⁸⁹ and the deepening of the Elbe River in Hamburg⁹⁰ are two more examples of projects temporarily delayed by non-governmental organisations.

Finally, *equipment, vehicle, wagon and locomotive manufacturers* influence the speed and performance of material, information flow and transshipment processes as well as noise and pollutant emissions.⁹¹

Each of the introduced actors focuses on its own viability, liquidity and individual company value growth. The different operative challenges are reflected by specific target systems and key figures. These key figures allow SC actors to evaluate corporate activities according to their impact on corporate value.

⁸⁶ cf. Stölzle et al. (2010); Stölzle et al. (2009).

⁸⁷ For details regarding the impact of transport policy on the integration of CT into SC concepts see section 2.3.

⁸⁸ See for instance web pages of NGOs <http://www.stuttgart21-ja-bitte.de/> or <http://www.kopfbahnhof-21.de/> and the official web page <http://www.das-neue-herz-europas.de/default.aspx>.

⁸⁹ See for instance Fraport (2011).

⁹⁰ cf. N.N. (2009).

⁹¹ See for instance VÖV (2008), pp. 38.

2.1.3.4 Challenge 3: Focus on Individual Company Value Growth

Companies increasingly focus on financial key figures and company value growth. Value-oriented management or the 'value-based view' is the most popular stream of strategic management.⁹² Owing to its service character, the quantification of logistics and the economic value added (EVA) of SCM is a special challenge.⁹³

There are different approaches to identify the EVA of SCM. Basically, the parameters influencing company value are connected with the driving parameters anchored in operative SC processes. The target dimensions mostly applied are yield, operating expenditure, floating capital and invested capital.⁹⁴

The differing operative challenges and the value orientation of single SC actors and CT actors are reflected by the applied target systems and their operationalisation in terms of key figures. These target systems include several conflicts. One example is that procurement activities aiming at a cost reduction are contrary to quality or supplier flexibility. In manufacturing the utilisation of production capacities does prejudice efficient storage and distribution because of set-up costs and lot size questions.⁹⁵ Several other target conflicts have been broadly discussed in practice and research.⁹⁶ These trade-off situations have to be considered when shortage costs are compared with storage costs or when transport speed is assessed with respect to transport costs (transport mode choice).⁹⁷

2.1.4 Vulnerability of Integrated SC Concepts

The cross-company integration of material and information flow processes is the basis of SC actors meeting customer demand, but it also causes vulnerability and mutual dependencies. As shown in the previous section, product availability is one key element for customer orientation. Interruptions in the material and information flow can quickly cause delivery disruption at the customer interface because of low inven-

⁹² cf. Horváth et al. (2001), pp. 273; Karrer (2006), pp. 156; Möller (2003), p. 58.

⁹³ cf. Karrer (2006), p. 2; Pfohl (2010), pp. 24. There are different scientific publications with the quantification and measurement of logistics and SC activities to the corporate value and at the development of recommendations for SCM based on value-oriented key figure hierarchies. See Alicke (2003); Arnold (2002); Hofmann et al. (2009); Jehle (2004); Marbacher (2001), p. 251.

⁹⁴ cf. Karrer (2006), pp. 163; Lambert et al. (2001), p. 12.

⁹⁵ See publications considering the operations scheduling dilemma. e.g., Nyhuis et al. (2008), pp. 4; Pfohl (2010), pp. 33.

⁹⁶ Such as Pfohl (2010), pp. 33.

⁹⁷ Such as *Ibid.*, pp. 33.

tory levels. This increases the dependency among SC members and increases SC vulnerability.

The *infrastructure shortages* in European hinterland and *delays in the port processes* endanger time critical, global SC concepts. Most imported or exported goods enter and leave Europe via North Sea ports. Imported goods arrive at a few main ports in Europe, such as Rotterdam, Antwerp, Hamburg and Bremerhaven. At these main hubs, the goods are either bundled for sea haulage or distributed to their destinations in Europe.

Figure 2 - 3 shows recent infrastructure shortages in Germany. The red points out the rate of delays and congestions in road transport. The situation in Germany is representative of further European regions.⁹⁸ The figure shows that the goods for southbound transport can be affected by infrastructure shortages. Plain to see are congestions in the Ruhr area. All transport coming from Europe's biggest port in Rotterdam must pass this region.⁹⁹

Not only European roads, but rail and water hinterland infrastructure suffer significant capacity shortages. However, in comparison, the rail and water infrastructure still has free capacity depending on the transport relation and time.

⁹⁸ cf. EK (2005).

⁹⁹ cf. Planco (2007), pp. 5.

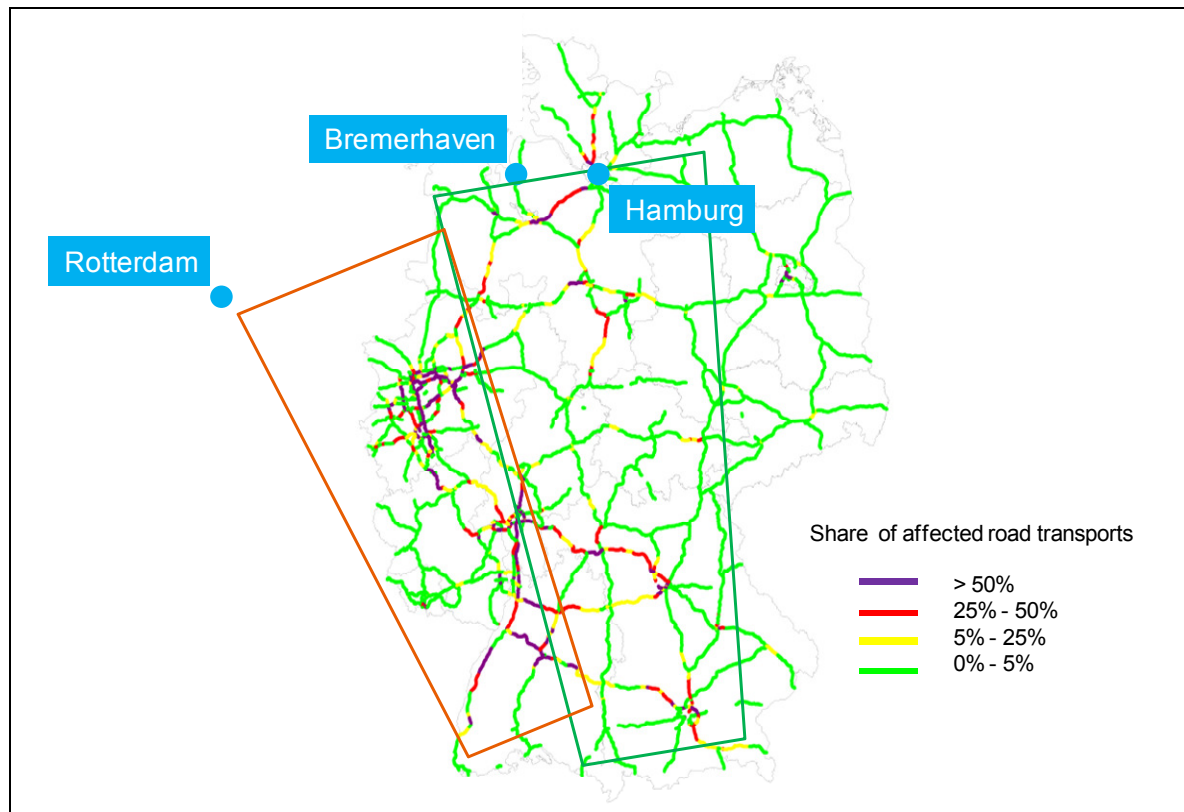


Figure 2 - 3: Road infrastructure shortages in Germany.¹⁰⁰

The previous paragraph showed the meaning of European infrastructure availability on the performance of global SCs. Thus, *transport policy* is a further central aspect for the design of global SCs. The development of transport policy and implementation take place at all political levels – local, regional, national and EU. National transport policies are crucial for infrastructure development. This applies to rail, road and waterway infrastructure as well as to interconnection points such as ports, terminals, logistics parks, maintenance and traffic management. However, transport policy influences global SCs through instruments such as regulations, traffic-specific taxes and duties, infrastructure development as well as international harmonisation and standardisation¹⁰¹.

Although the integration of material and information flow processes is necessary to meet customer demand and improve SCP, there are several examples of negative consequences for upstream and downstream SC actors caused by one company. These secondary failures and disruptions of material flow processes for downstream actors

¹⁰⁰ cf. Ibid., p. 7. For details on the effect of infrastructure shortages see cf. Stölzle et al. (2009). For the impact of transport policy see section 2.2.3.2.

¹⁰¹ For the further consideration of the impact of transport policy on SCs, see section 2.2.3.2

are defined as '*vulnerability*'. Such a situation requires flexible reactions and fast adaptations by all SC actors. To avoid growing storage volume, the production and procurement processes of all suppliers and sub-suppliers as well as distribution processes are to be suspended. The specific transport processes must remain available. At the same time, all SC actors have to prepare for the following ramp up situation.¹⁰² The following example shows the vulnerability of SCs caused by snowball effects. In 2001, a fire in a Mexican *Philips* plant led to a three-week production disruption at the Swedish company *Ericsson*.¹⁰³ The onset of foot-and-mouth disease in Great Britain in 2001 led to production stops at *Volvo* and *Ford*¹⁰⁴ and quality variations because of constructive changes at the diesel pumps for direct injection systems at *Bosch* led to breakdowns in nearly all German automotive factories in 2005.¹⁰⁵ Such series of reactions are also called 'snowball effects'.¹⁰⁶

SC integration faces several further challenges. Companies are members of more than one SC ('*multi-memberships*'). The comprehensive integration of all business partners is from an economic point of view not always reasonable because some relationships are only short-term. The variety of publications on dyadic cooperation proves that the management of one-to-one relationships is already a demanding task.¹⁰⁷ Trust and power aspects contradict close partnerships and integration. In practice, these problems lead to an integration of only the immediate vertical and horizontal SC partners of the focal company. Diseconomies of SC integration also arise from rising managing complexity, decreasing flexibility, financial risks and the loss of specific competencies. Furthermore, companies run risks by getting into dependencies, loss of freedom and draining knowhow.

There is a number of measures and instruments to support integration activities. The following section presents the results of a comprehensive literature review on integrative measures and instruments with regard to technical and organisational integration aspects.

¹⁰² Further examples are the onset of foot-and-mouth-disease in Great Britain in 2001 leading to production stops at Volvo and Ford (cf. Pfohl (2002)). In 2005 nearly all German automotive factories broke down due quality variations caused by the constructive change in the diesel pump for direct injection systems at Bosch (cf. Kersten et al. (2007), p. 13). Such series of reactions are also called 'snow ball effect'. cf. Sheffi (2005), pp. 143.

¹⁰³ cf. Norman et al. (2004), p. 441; Svensson (2004), p. 729.

¹⁰⁴ cf. Pfohl (2002).

¹⁰⁵ cf. Kersten et al. (2007), p. 13.

¹⁰⁶ cf. Sheffi (2005), p. 143.

¹⁰⁷ See for example Fabbe-Costes et al. (2007), p. 843; Sahin et al. (2005), pp. 579; Vachon et al. (2006), pp. 795.

2.1.5 Measures and Instruments for SC Integration

The literature provides a number of concrete measures and instruments to support customer orientation and material and information flow integration in SCs. Cooper (1997) distinguished integration activities into managerial and behavioural as well as technical and organisational management components.¹⁰⁸ Managerial and behavioural measures cover employee behaviour (e.g., election, advanced training, hospitalisation, incentive systems). The technical and organisational management components focus on material and information flow processes, structures and organisational aspects.¹⁰⁹

According to Cooper et al. (1997), the technical and organisational management components encompass management components regarding the I&C flow facility structure, workflow and activity structure, organisational structure, planning and control methods and product flow facility structures. Furthermore, definitions of architecture and components of I&C systems as well as on the material flow systems are considered. Figure 2 - 4 shows these considerations and illustrates allocating the management components into two main categories.

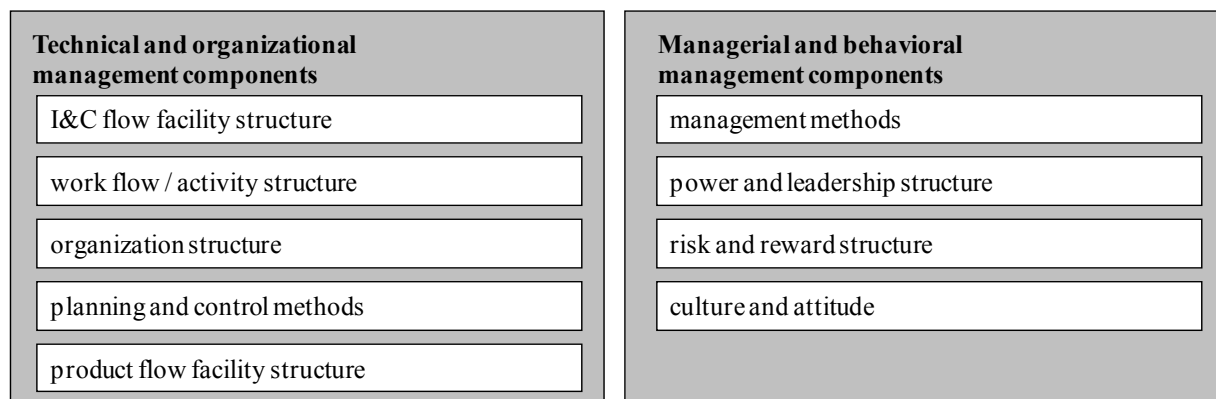


Figure 2 - 4: Management components of SC integration.¹¹⁰

The thesis in hand excludes managerial and behavioural management components from deeper consideration. This focus reduces the complexity of the given problem formulation and corresponds to the neutral and non-actor-specific research perspective. The exclusion of problems regarding behavioural aspects, culture and leadership supports the perspective on the potential and chances of CT integration.

¹⁰⁸ cf. Cooper et al. (1997), p. 12; Häusler (2001) distinguished between integration measures on a socio-emotional and formal-rational level. cf. Häusler (2001), p. 225.

¹⁰⁹ cf. Cooper et al. (1997), pp. 12; Heusler (2004), p. 225.

¹¹⁰ With adaptations in accordance with Cooper et al. (1997), p. 12.

Following Cooper's definition of physical and technical management components (cf. section 2.1.2), an encompassing literature review was conducted. Several sub-categories of specific technical and organisational measures and instruments of the five main categories could be identified.

- (1) I&C flow facility structure,
- (2) Workflow/activity structure,
- (3) Organisational structure,
- (4) Planning and control methods and
- (5) Product flow facility structure.

The developed catalogue of integrative measures and instruments serves as the basis for the examination of suitable integration measures for the performance-oriented integration of CT into SC concepts (cf. section 4.3).

There are measures that cannot be clearly allocated to one group. Furthermore, it must be considered that integrative measures do not work in isolation. Technical and organisational as well as managerial and behavioural measures work hand in hand. Usually groups of integrative measures are applied together. Thus, for an encompassing integration, managerial and behavioural approaches have to be considered, too. Figure 2 - 5 provides an overview of the categorisation of technical and organisational management components for the integration of CT into SC concepts.

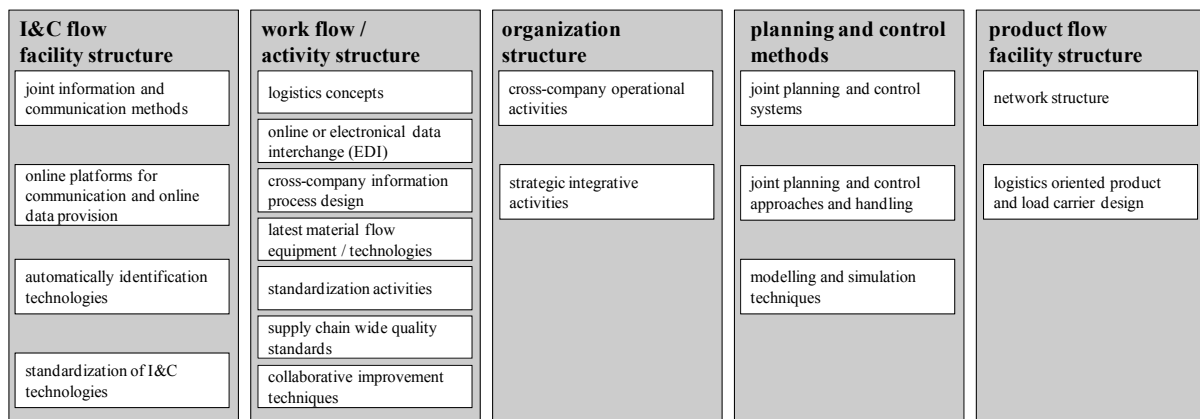


Figure 2 - 5: Overview of the technical and organisational management components derived from the literature.¹¹¹

¹¹¹ Own illustration based on literature review.

(1) I&C flow facility structure

Information technology (IT) enables the sharing of large amounts of data between companies. Several authors have discussed the critical role of IT on SCM activities.¹¹² Cooper et al. (1997), for instance, stated that the type and frequency of information passed and updated among SC actors strongly influences SC efficiency.¹¹³ I&C flow facility structure is suggested as the first measure for a SC integration project.¹¹⁴ The integration of I&C systems reduces technical barriers and incompatibilities and thus, improves communication between SC actors.¹¹⁵ Often, transaction cost theory serves as an explanation of the effect of IT systems' integrations. For instance, Johnson et al. (2007) confirmed the relationship among the availability of IT, SC applications and decreasing transaction costs.¹¹⁶ However, some authors have pointed out that it is not sensible to integrate all SC members in terms of I&C technologies.¹¹⁷ The availability of a well-functioning I&C flow facility structure serves as the basis of a number of further integrative measures, especially for the setup of joint planning and control measures.

The literature review identified four main groups of integrative measures and instruments regarding I&C flow facility: the application of (1) integrated I&C methods, technologies and systems, the usage of (2) online platforms and online data provision, the use of (3) automatically identification technologies and (4) the standardisation of I&C technologies.

Table 2 - 1 provides an overview of the publications dealing with integrative measures suitable from the field of I&C flow facility structure classified according to these four categories. If possible, publications are classified according to relevant sub-topics.

¹¹² See for instance Kearns et al. (2003); Vickery et al. (2003); Vanpoucke et al. (2009); Welker et al. (2008).

¹¹³ cf. Cooper et al. (1997).

¹¹⁴ cf. Ibid., p. 78.

¹¹⁵ cf. Bowersox et al. (2002); Li-Ling et al. (2009), p. 101; Sanders (2007); Vickery et al. (2003).

¹¹⁶ cf. Johnson et al. (2007).

¹¹⁷ See for instance Das et al. (2006); Vanpoucke et al. (2009), p. 1217; Williamson (1996).

integrated I&C methods, technologies and systems	latest I&C sharing systems, methods and technologies: e.g., Bagchi & Skjoett-Larsen (2002); Murphy & Farris (1993); Chen & Paulraj (2004); Handfield & Bechtel (2002); Sanders (2007); Stefansson (2002) integrated databases, warehouses and collaboration systems: e.g., Murphy & Farris (1993); Chen & Paulraj (2004); Cheng (2010); Dehning et al. (2007); Fiala (2005); Frohlich & Westbrook (2002); Handfield & Bechtel (2002); Ke & Wei (2007); Kobayashi et al. (2003); Li et al. (2006a); Sanders (2007); Zhu & Kraemer (2002) joint measure, control and sharing of process data: e.g., Murphy & Farris (1993); Chen & Paulraj (2004); Das et al. (2006); Frohlich & Westbrook (2002); Vanpoucke et al. (2009); Welker et al. (2008); Zhu & Kraemer (2002)
online platforms and online data provision	e.g., Devaraj et al. (2007); Frohlich & Westbrook (2002); Hill & Scudder (2002); Jayanth & Keah-Choon (2010); Mukhopadhyay & Kekre (2002); Zhu & Kraemer (2002)
automatically identification technologies	bar coding, RFID-technology etc.: e.g., Amador & Emond (2010); Chao et al. (2007); Chao et al. (2007); Delen et al. (2007); Klein & Thomas (2009); Lee et al. (2011); Lin (2009); Anand et al. (2009); Lin (2009); López (2011); Ngai & Riggins (2008); Sarac et al. (2010); Shin et al. (2011); Strassner & Fleisch (2005); Sundaram et al. (2010); Tajima (2007); Véronneau & Roy). sensor technology: e.g., Amador & Emond (2010); Anderson & Hong (2008); Ilgin & Gupta (2010); López (2011); Makinwa (2010); Shin et al. (2011); Wada et al. (2011); Yang et al. (2010)
standardisation of I&C technologies	e.g., Akkermans & van der Horst (2002); Carlson et al. (2001); Polo-Redondo & Cambra-Fierro); Gunasekaran & Ngai (2004); Jagdev & Thoben (2001); Keil et al. (2001); Lancioni et al. (2000); Polo-Redondo & Cambra-Fierro (2008); Sanders (2008); Shin & Leem (2002).

Table 2 - 1: Literature review of integrative measures from the field of I&C flow facility structure.

(2) Workflow activity structure

Work structure indicates how tasks and activities are performed in a SC.¹¹⁸ Integrative measures of this group concern process structure and thus, directly influence the types, structures and sequences of material and information flow processes.¹¹⁹

In this category, the literature review identified five types of integrative measures and instruments: (1) online or electronic data interchange, (2) latest material flow equipment and technologies, (3) standardisation activities, (4) SC-wide quality standards and (5) collaborative improvement techniques. Table 2 - 2 provides an overview of the publications on integrative measures from the field of workflow and activity structure classified according to these seven categories. If sensible, publications are classified according to relevant sub-topics.

¹¹⁸ cf. Andrews et al. (1994); Ellram et al. (1990); Hewitt (1994).

¹¹⁹ cf. Kannan et al. (2005); Kim et al. (2011); Kobayashi et al. (2003); Liu et al. (2005); Nielsen et al. (1995); Li et al. (2006b); Qiu et al. (2006); Salema et al. (2010); van der Aalst et al. (2007); van der Aalst et al. (2003); Vrijhoef et al. (2000).

online or electronic data interchange (EDI)	<p>information sharing for B2B or B2C online purchasing: e.g.,Mukhopadhyay & Kekre (2002); Frohlich & Westbrook (2002); Zhu & Cote (2004); Kong et al. (2004); Li & Lin (2006)</p> <p>customer configuration/customisation of designated goods: e.g.,Murphy & Farris (1993)</p> <p>online auctions: e.g.,Murphy & Farris (1993); Pflughoeft et al. (2003); Poirier & Quinn (2004); Poirier & Quinn (2004); Ranganathan et al. (2004); Zhu & Kraemer (2002)</p> <p>demand oriented web based information sharing: for instance sharing of real-time point-of-sales data and sales forecast: e.g.,Aviv (2001); Cachon & Lariviere (2001); Choi (1995); Christopher (2005a); Jaber et al. (2010); Anand et al. (2009); Wu & Chen (2006)</p> <p>customer profiling and customer relationship management (CRM): e.g.,Bönte (2008); Dupre & Gruen (2004); Frohlich & Westbrook (2002)</p> <p>supply-oriented information sharing: e.g.,provision of inventory ordering policies, inventory levels: e.g.,Murphy & Farris (1993); Frohlich & Westbrook (2001); Krajewski & Wei (2001); Yang et al. (2009); Zhu & Kraemer (2002)</p> <p>master production schedules: e.g.,Barua et al. (2000); Das et al. (2006); Frohlich & Westbrook (2001); Krajewski & Wei (2001); Lancioni et al. (2000)</p> <p>collaborations on net material requirements: e.g.,Murphy & Farris (1993); Cachon & Lariviere (2001); Krajewski & Wei (2001); Zhu & Kraemer (2002)</p>
latest material flow equipment / technologies	<p>e.g., Abacoumkin & Ballis (2004); Agersekov et al. (1983); Arnold et al. (2004); Ballis & Golias (2002); Ballis & Golias (2004); Basu & Wright (2008); Chao et al. (2007); Dias et al. (2010); Erera et al. (2005); Evers et al. (1996); Greeff et al. (2004); Halevi (2001); Kreutzberger et al. (1999); Macharis & Pekin); Meyer et al. (2009); Min & Zhou (2002); Özbayrak et al. (2007); Panayides & Song (2008); Sharma et al. (1999); Sheu (2002); Stefanovic et al. (2009); Thomas & Griffin (1996); Walker et al. (2008); Wang & Cullinane (2006)</p>
standardisation activities (material and information flow technologies)	<p>e.g., Lenzen et al. (2007); Akkermans et al. (2003); Akkermans & van der Horst (2002); Carlson et al. (2001); Gunasekaran & Ngai (2004); Hatteland (2004); Keil et al. (2001); Lancioni et al. (2000); Polo-Redondo & Cambra-Fierro (2008); Sanders (2008); Shin & Leem (2002)</p>
SC-wide quality standards (e.g., DIN/ISO 9000 Six Sigma etc.)	<p>e.g., Anand et al. (2009); Basu (2008); Bessant et al. (1994); Buttermann et al. (2008); Foster Jr (2008); González-Benito et al. (2003); Kannan & Tan (2005); Kaynak & Hartley (2008); Parast); Sroufe & Curkovic (2008); Truscott (2003); Sroufe & Curkovic (2008); Stanley & Wisner (2001); Yeung (2008); Lo et al. (2009)</p>
collaborative improvement techniques	<p>Collaborative continuous improvement techniques: e.g.,Choi (1995); Jaber et al. (2010); Anand et al. (2009); Wu & Chen (2006)</p> <p>poka yoke: e.g.,Basu (2008); Barash); Harvey (1998); Lee & Lim (2005); Plenert (2007); Schippers (2001); Tang & Tomlin (2008); Truscott (2003); Tsou & Chen (2008)</p>

Table 2 - 2: Literature review of integrative measures from the field of workflow and activity structure.

(3) Organisational structure

According to Lambert & Cooper (2000), organisational measures influence both the individual firm and the SC.¹²⁰ The literature review showed up two groups of organisational measures and instruments: (1) cross-company operational activities, such as cross-functional teams account managers and dedicated planners for one buyer, and (2) strategic integrative activities, such as joint ventures and the creation of quasi-firms. Table 2 - 3 provides an overview of the publications on integrative measures from the field of organisational structure classified according to these two categories.

cross-company operational activities (e.g., cross-functional teams / personnel; account managers etc.)	e.g., Alicke (2003); Cooper et al. (1997) Bagchi & Skjoett-Larsen (2002); Droge et al. (2004); Moffat (1998); Moore & Antill (2001); Lee-Kelley & Sankey (2008); Loo (2003); Panayides & Venus Lun (2009); Perona & Saccani (2004); Sako & Helper (1998); Thamhain (2004); Wang et al. (2005)
strategic integrative activities (e.g., Mergers & Acquisitions (M&A) activities; creation of quasi-firm; joint ventures etc.)	e.g., Alicke (2003); Cousins et al. (2006); Jayaram & Tan (2011); Kandemir & Hult (2005); Kroes & Ghosh); Ku et al. (2007); Petersen et al. (2005); Sarkis et al. (2011)

Table 2 - 3: Literature review of integrative measures from the field of organisational structure.

(4) Planning and control methods

The planning and control of operations is central to a constant and stable cross-company material and information flow. According to Lambert & Cooper (2000) and Alicke (2003), the joint planning of processes improves the quality of material flow processes.¹²¹ The literature review identified three main groups of planning and control measures: 'classic' (1) joint planning and control systems, (2) joint planning and control approaches and handling and the usage of (3) modelling and simulation techniques. Table 2 - 4 gives an overview of the integrative measures from the field of planning and control methods. If sensible, publications are classified according to relevant sub-topics.

¹²⁰ cf. Lambert et al. (2000).

¹²¹ cf. Alicke (2003), p. 67; Lambert et al. (2000), p. 71.

joint planning and control systems (e.g., ERP, PPC and APS (advanced planning and scheduling) systems and modules etc.)	e.g., Afshin Mansouri et al. (2010); Alicke (2003); Amaral & Kuettner (2008); Arshinder et al. (2008); Barua et al. (2000); Bergström & Stehn (2005); Bose et al. (2008); Brun et al. (2006); Carr & Kaynak (2007); Chang et al. (2008); Fleischmann et al. (2003); Frohlich & Westbrook (2002); Fugate et al. (2006); Giunipero et al. (2008); Grawe et al. (2009); Henning et al. (2009); Hvolby & Steger-Jensen (2010); Gibson et al. (2005); Henning et al. (2009); Hvolby & Steger-Jensen (2010); Jonsson et al. (2007); Jung & Lee (2010); Mabert et al. (2003); Newell et al. (2003); Poirier & Quinn (2004); Rajagopal (2002); Rutner et al. (2003); Sanders (2007), Shobrys & White (2002); Soltani & Sadjadi (2010); Su & Yang (2010); Stadtler (2005); Verwijmeren (2004); Zachariassen (2008); Zoryk-Schalla et al. (2004).
joint planning and control approaches	improved planning techniques, joint data mining, shared sales forecasts: e.g., Barua et al. (2000); Cachon & Lariviere (2001); Devaraj et al. (2007); Frohlich & Westbrook (2001); Lee et al. (1997). joint capacity and demand planning through CPFR: e.g., Barua et al. (2000); Cao & Zhang (2010); Chan & Zhang (2011); Esper & Williams (2003); Frohlich & Westbrook (2002); Hill & Scudder (2002); Lee et al. (1997); Lee et al. (2011); Lyu et al. (2010); Mert et al. (2007); Pibernik et al. (2007); Ramanathan & Muijldermans (2011); Sari (2008); Son & Sheu (2008); Whipple et al. (2010) autonomous control approaches: e.g., Cimino & Marcelloni (2011); Hua et al. (2003); Lu & Chen (2010); Scholz-Reiter et al. (2008); Siemieniuch & Sinclair (2002); Hülsmann & Windt (2007); Windt & Bendul (2006); Windt et al. (2008)
modelling and simulation techniques	reference models: e.g., Power (2005); Maier et al. (2002); Shin & Leem (2002); Röder & Tibken (2006); Simon et al. (2007); Persona et al. (2007); Sarimveis et al. (2008), Trappey et al.); Verdouw et al. (2010) modelling and simulation approaches: e.g., Biethahn et al. (1999); Biswas & Narahari (2004); Biswas & Narahari (2004); Caputo et al. (2003); Chan & Zhang (2011); Chatfield et al. (2009); Elmahdi et al. (2006); Escudero et al. (1999); Georgiadis et al. (2005); Gunasekaran (2004); Hung et al. (2006); Li et al. (2006b); Mahnam et al. (2009); Manuj & Mentzer (2008); Meixell & Norbis (2008); Mizgier et al. (2010); Özbayrak et al. (2007); Rizzoli et al. (2002); Mele et al. (2006); Mizgier et al. (2010); Neuro & Pinto (2004); Röder & Tibken (2006); Sinha et al. (2011); Rodriguez-Rodriguez et al. (2011); Sarac et al. (2010); Sundaram et al. (2010); Trkman et al. (2007); Varma et al. (2007)

Table 2 - 4: Literature review of integrative measures from the field of planning and control methods.

(5) Product flow facility structure

Product flow facility structure refers to the logistics-oriented product and load carrier design as well as packaging, which are approaches to improve handling, loading and capacity usage for the production, distribution and transport of goods, and thus, the interruption-free flow of information and material.¹²² Table 2 - 5 provides an overview of the integrative measures of product flow facility structure.

logistics-oriented product and load carrier design	e.g., Diabat & Govindan (2011); Güngör et al. (2011); Hua et al. (2011); Kaijie et al. (2007); Ko et al. (2011); Liu (2011); Rostamzadeh & Sofian (2011); Smith & Yen (2010); Sroufe & Curkovic (2008); Wang & Zhang (2010); Xia & Chen (2011)
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Table 2 - 5: Literature review of integrative measures from the field of product flow facility structure.

¹²² Bretzke et al. (2010) introduced different approaches to a logistics-oriented product design, e.g., the reduction of bulkiness to reduce the required transport capacity, the reduction of product weight ('light weight construction') to diminish fuel consumption, the enhancement of the products' useful life to reduce the disposal processes, the modularisation of products and standardisation of products or product modules. cf. Bretzke et al. (2010), pp. 79.

The measures and instruments introduced in this section support the integration of material and information flow processes and thus, SCP. The complexity of CT exacerbates the integration of material and information flows because of several inherent and external challenges. The main characteristics, structures and elements of CT concepts are introduced in the following section.

2.2 Coping with CT Complexity in SCs

This section addresses CT's inherent challenges in the integration into SC concepts. CT underlies several market- and production-related disadvantages in comparison with unimodal road transport. The characteristics and challenges of CT concepts must be known to be successfully integrated. Thus, this section provides an overview of the application fields of CT concepts, discusses different aspects of CT service complexity and addresses the characteristics and challenges exacerbating the competitive situation with unimodal road transport.

2.2.1 Application Fields of CT

Economic and political players increasingly perceive CT as a promising solution to deal with problems in road transport. It is assumed that the combination of rail and road transport may prospectively even increase SCP improvements in comparison with unimodal road transport.¹²³ However, in comparison with unimodal road transport, CT has some inherent and market-related disadvantages.

Intermodal transport is defined as the *usage of one or multiple carriers for the transport of an empty or filled load carrier*. The main distance is covered by rail, ocean or inland vessel, whereas the comparably short pre- or ongoing transport is accomplished by road. CT describes a subset of intermodal transport and it is commonly applied to the carrier combination of road and rail transport.¹²⁴ However, often the terms combined, intermodal and multimodal transport¹²⁵ are synonymously used.¹²⁶ The thesis in hand focuses on the combination of rail and road transport. This CT concept has an inner-continental character, but it is often combined with previous inter-continental

¹²³ For instance, in the case of significantly rising energy prices as well as growing infrastructure shortages.
¹²⁴ cf. Hoffmann (2007), p. 14; Polzin (1999), p. 81.

¹²⁵ Usually the term 'multimodal transport' stands for the combination of at least three carriers.

¹²⁶ cf. Hoffmann (2007), p. 14. A combination with air freight is possible too, but is rather uncommon.

water transport.¹²⁷

The term '*CT concept*' determines all necessary technical, organisational, player, process and carrier definitions to ensure a stable time-, quality- and cost-defined transport of goods from a certain source to a delivery point by a combined rail and road transport with at least one transshipment process.

Advantages of CT

CT concepts allow the integration of rail -transport into SC concepts in regions without trackage systems or side tracks. CT joins the inherent advantages of the different carriers and, thus, means an affordable and environmental alternative to unimodal road transport. It is flexible as road transport is used to supply geographically distributed shippers and customers and it is characterised by the low emissions level and cost efficiency of rail transport for large transport quantities over long distances. In particular, the potential emissions reduction and the associated image effect is one main advantage for shippers and 3PLs to integrate CT into SC concepts. In 2008, the Association Materials Management, Purchasing and Logistics (AMMPL) published a survey on the reduction of CO₂ emissions.¹²⁸ In total, 170 German production and retail companies were surveyed according to their modal splits and the specific reasons for their transport carrier choices. The objective was to understand carrier choice and to analyse the relationship between CO₂ emissions and modal split. The survey showed that the main reason for shippers to switch from road transport to rail or CT is the improvement in CO₂ emissions balance.¹²⁹

CT has further advantages in comparison with unimodal rail transport. With the liberalisation of the European railway market, state rail carriers focus on CT rather than on single wagon freight transport. High fixed costs, the competitive situation and the resulting need for rationalisation are the reasons.

In Norway, Denmark, Spain and Great Britain, there is no single wagon freight transport because of the high level of fixed and availability costs.¹³⁰ The Italian, French, Austrian and Swiss state railways have significantly minimised their single wagon transport nets in the past decade.¹³¹ In 2002, the *DB AG* reduced operated railway sid-

¹²⁷ cf. Wang et al. (2010).

¹²⁸ cf. Wittenbrink (2008).

¹²⁹ cf. Ibid., p. 10.

¹³⁰ cf. DBAG (2007), p. 7.

¹³¹ cf. VAP (2010); Prograns (2007), pp. 30, 50.

ings from approximately 2100 by 1200 (Mora C)¹³² to make the system more economical. According to de Jong (2011), single wagon freight transport at DB AG was dependent on few big shippers, but 70% of the customers generated only 5% of the revenues. The *DB AG* aimed for a cost reduction of approximately 250 Mio. Euro.¹³³

Today, the Swiss and French state railways perceive CT as central aspects for the financial reorganisation of freight transport divisions.¹³⁴ In Germany, the *DB AG* is increasing activities in the field of CT, too.¹³⁵ Furthermore, the traditional unimodal rail transport specific wagons are necessary. Thus, round trips are difficult to realise. According to an expert of the German consulting company *KombiConsult* (2011), in CT 85–100% of transport is paired.¹³⁶

Several transport political regulations have improved the competitive situation of CT in comparison with unimodal road transport. In Germany, transport vehicles, restricted to pre- and ongoing haulage of CT, are exempt from motor vehicle tax.¹³⁷ Furthermore, there are exemptions from driving bans for the pre- and ongoing haulage to the next closest shipping or receiving terminal. For below 200 km pre- or ongoing haulage, the exemption also encompasses Sundays and holidays.¹³⁸ Furthermore, the maximum weight for pre- and ongoing transport has been increased to 44 tons.¹³⁹ The Swiss government subsidises the transalpine CT, namely the terminal building and shipments.¹⁴⁰

Typical Products for CT

Generally, goods with stable and high transport volumes in both directions are affine for CT. Today, especially, dry, free-flowing and fluid hazardous goods are transported via CT.¹⁴¹ For such transport, special load carriers are used. Thus, unpaired transport is accepted since cleaning costs often exceed idle costs. Increasingly bulk cargo is transported in boxes and so-called ‘bulk containers’.¹⁴² Furthermore, heavy goods, such as

¹³² cf. VDV (2000).

¹³³ cf. De Jong et al. (2007).

¹³⁴ cf. Heinrici (2011), p. 33.

¹³⁵ cf. De Jong et al. (2007).

¹³⁶ cf. Heinrici (2011), p. 33.

¹³⁷ cf. § 3 No. 9 a KraftStG. (Online available under: http://www.gesetze-im-internet.de/kraftstg/__3.html).

¹³⁸ cf. § 30 StVO. (Online available under http://bundesrecht.juris.de/stvo/__30.html).

¹³⁹ *Kombiverkehr* provides a comprehensive calculation example pointing out the economical advantages of this. cf. *Kombiverkehr* (2011).

¹⁴⁰ For further details of transport policy see section 2.2.3.2.

¹⁴¹ cf. Seidelmann (2010), pp. 31.

¹⁴² cf. Müller (2011).

metals or building materials, are commonly transported by CT.¹⁴³ Lately, also specific trailers for the CT of glass have been offered.¹⁴⁴

Owing to the high fixed costs level, CT is commonly applied to long and international distances. Several publications have stated these minimum transport distances. However, authors have stated that CT is not economically possible on distances below 300 km.¹⁴⁵ However, latest examples show that CT can also be integrated into SCs for short distances.¹⁴⁶

CT Quantities in Europe

Table 2 - 6 gives an overview of transport quantities in tons and TEU in Europe for domestic and international transport. The table shows that domestic inland transport comprises approximately two thirds in comparison with domestic continental transport. Likewise, in international transport continental transport comprises approximately two thirds and container hinterland transport the other third.

CT market segment	continental transport		container hinterland transport		total CT	
domestic (in tons)	30 199 059	33.0%	61 313 241	67.0%	91 512 300	100%
(in TEU)	2 984 189	32.0%	6 341 401	68.0%	9 325 590	100%
international (in tons)	39 803 680	63.2%	23 226 120	36.8%	63 029 800	100%
(in TEU)	3 707 550	60.5%	2 415 730	39.5%	6 123 280	100%
all services	70 002 739	45.3%	84 539 361	54.7%	154 542 100	100%
in TEU	6 691 739	43.3%	8 757 131	56.7%	15 448 870	100%

Table 2 - 6: Transport quantities in CT (unaccompanied) in 2009 in tons and TEU.¹⁴⁷

As Table 2 - 6 shows, in Europe CT are predominantly applied to the so-called '*hinterland*'-distance from the North or Mediterranean Sea into central Europe and for alpine transit.¹⁴⁸ Figure 2 - 6 illustrates the distribution of European transport quantities in CT. Restrictive regulations support the transalpine CT.¹⁴⁹ For instance, Switzerland has set up a programme to reduce road transport volumes by two thirds between 2001 and 2018.¹⁵⁰ In 2009, Austria enacted a law that progressively restricts the transport of

¹⁴³ cf. Part 3 § 34 Absatz 6 Nummer 6 StVZO. (online available under <http://www.stvzo.de/stvzo/B3.htm#34> and <http://www.kombiverkehr.de/neptun/neptun.php/oktopus/download/58>).

¹⁴⁴ cf. Soller (2011), p. 18.

¹⁴⁵ cf. among others Seidelmann (1997).

¹⁴⁶ cf. Klaas-Wissing et al. (2010).

¹⁴⁷ cf. UIC (2010), pp. 26.

¹⁴⁸ cf. Ibid., p. 21.

¹⁴⁹ cf. Polzin (1999), p. 94.

¹⁵⁰ cf. BAV (2011b).

certain goods.¹⁵¹ For example, the unimodal road transport of wood and ceramics is prohibited and must thus, be shifted to rail.¹⁵²

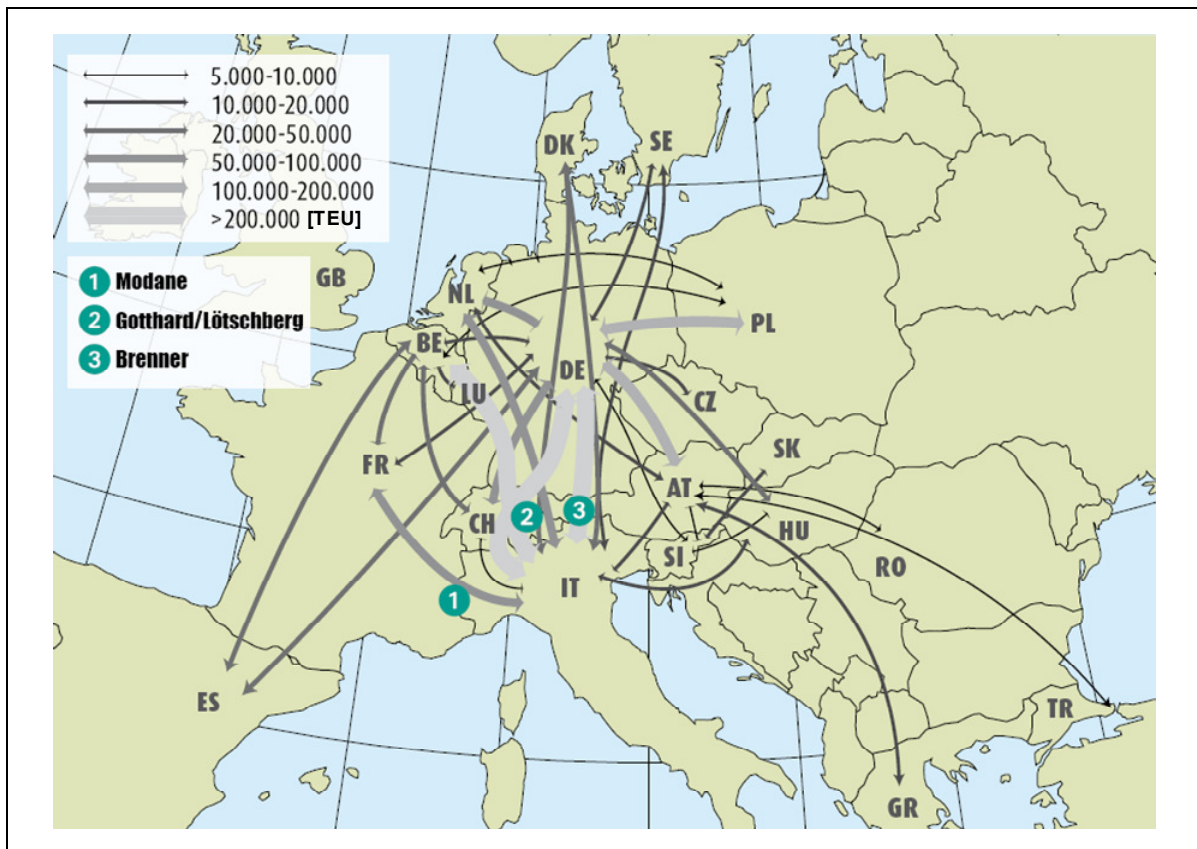


Figure 2 - 6: Alpine transit by unaccompanied CT.¹⁵³

Driven by the problems in unimodal road transport, CT is increasingly integrated into retail SCs.¹⁵⁴ There are first examples of the cost, time and quality neutral integration of CT for the inland transport of consumer goods. The main haulage is accomplished by rail transport and this seems to be economical, even for distances below 100 km.¹⁵⁵

These ‘*innovative*’ domestic and short distance CT concepts are the central interest of the thesis in hand. In comparison with ‘traditional’ transnational and long distance CT, the requirements for performance-oriented integration into SC concepts are particularly high. Thus, considerations and recommendations on the integration of short distance CT into SC concepts can easily be transferred to ‘classical’ CT services, since the competition between CT and unimodal transport over short distances is even more

¹⁵¹ cf. WKO (2011).

¹⁵² For details on the impact of European and national transport policy see section 2.2.3.2

¹⁵³ cf. Seidelmann (2010), p. 46.

¹⁵⁴ cf. Klaas-Wissing et al. (2010).

¹⁵⁵ For details see *ibid.*

distinctive.

For the performance-oriented integration of CT into SC concepts the characteristics of CT services as well as recent SC concepts must be known. Thus, the following section addresses the service complexity of the CT concepts.

2.2.2 Service Complexity of Combined Transport Concepts

This section addresses the characteristics of CT concepts leading to a comparably high level of service complexity. This complexity exacerbates the competitive situation to the unimodal road transport. It results from the inherent characteristics, namely the variety of different CT concepts, of CT actors, processes and structures and the external factors namely shippers' requirements and transport policy.

2.2.2.1 Inherent Challenges of Combined Transport

CT is characterised by several inherent challenges. CT requires additional processes and actors in comparison with unimodal road transport. Thus, the costs of CT services and the coordination effort for the transport service are comparably high.

In a CT concept, the transported goods are at least once transhipped at a specific terminal from rail to road or vice versa. Thus, in comparison with unimodal road transport *additional handling, planning and control processes* as well as *additional transport actors* (e.g., terminal operators, rail carriers, infrastructure operators etc.) are necessary for the transport of the same good. This increases *planning, control and coordination efforts*, requires additional time amounts and increases costs.

The *integration of rail transport into SC concepts* in general bears specific challenges. In 2008, the AMMPL analysed the specific disadvantages of integrating rail transport into SC concepts. In particular, its low speed and flexibility, low service level and lacking service customisation were criticised.¹⁵⁶ Furthermore, shippers claim that transport quantities are too small to fill at least one wagon.¹⁵⁷

CT concepts must deal with several *organisational and IT challenges*. Usually CT actors pass information only *dyadically*. The information is usually restricted to own performance. The *operative, shipment-related, service offer- and demand-related in-*

¹⁵⁶ cf. Wittenbrink (2008), pp. 7.

¹⁵⁷ cf. Ibid., pp. 7.

formation is usually actor-specific.¹⁵⁸ Integrated I&C systems are still missing. Media discontinuity inhibits the SC-wide information interchange and transparency about transportation processes. Reasons are the incompatibility of the used IT systems and the number of involved actors. The cross-company availability of information is the prerequisite for common planning and control processes and thus, for the integration of material and information flow processes.¹⁵⁹ For instance, delays and interruptions in information flows may cause bottleneck situations and additional waiting times, for instance because of a wrong capacity planning at a CT terminal. These delays may affect overall SCP in terms of utilisation, lead times and costs.

The missing IT systems are reflected by *missing organisational structures*. Generally, CT concepts lack a missing coordination element, coordinating and designing the shippers' costs and performance requirements. Shippers and 3PLs as the customers of CT services usually claim to have only one counterpart.¹⁶⁰ This coordinating role and interface can be accomplished by each of the CT actors. Owing to these often dynamically changing role allocations, the marketing and quality management are complicated. Often there is *no planning and control entity* in the CT chain at all.¹⁶¹

Next to these general inherent challenges, the diversity of CT services exacerbates the dealing with CT in comparison with unimodal road transport. In particular, shippers are put off by this – at first glance – confusing variety of different concepts.

2.2.2.2 Diversity of CT Services

This section addresses the different classifications of CT services. In particular, the different types of service production are of interest.¹⁶²

There are different classification approaches for CT services. For instance, the classification into seaport hinterland and overland transport is commonly applied. Surface transport means the transport of swap bodies¹⁶³ or semi-trailers. The seaport hinterland transport is dominated by the transport of ocean containers.¹⁶⁴ For this transport cranable load carriers are required. Today, the share of these cranable load carriers is only

¹⁵⁸ cf. Taylor et al. (2000), p. 15; Hoffmann (2007), p. 72.

¹⁵⁹ cf. section 2.2.1.

¹⁶⁰ cf. UIC (2010), pp. 13.

¹⁶¹ cf. Hoffmann (2007), pp. 72.

¹⁶² For the development of specific practical recommendations on the integration of SC concepts a specific classification is necessary.

¹⁶³ There are other names, such as swap container, interchangeable container, etc.

¹⁶⁴ cf. VÖV (2008), p. 34.

15% (container (14%), cranable swap body and semi-trailers (1%), not cranable swap body and semi-trailers 45%, other trucks 40%).¹⁶⁵ For transshipment with a crane or reachstacker¹⁶⁶ the transport unit is grasped from above (vertical transshipment). 'Horizontal' transshipment technologies move the good horizontally, without vertically raising it. Here, either the truck or the wagon is equipped with transshipment equipment such as tracking and hydraulic systems to autonomously shift the transport.¹⁶⁷

The market segments of CT are often classified according to the type of load carriers. Thus, container and piggyback transport can be distinguished. Piggyback transport includes roll-on/roll-off, semi-trailer and swap-body transport.¹⁶⁸ Roll-on/roll-off transport means the loading of transport units with self-propelled goods. A special type of roll-on/roll-off transport is the so-called 'rolling road' (horizontal transshipment).¹⁶⁹ Trucks with or without trailers are transported on specific low floor or so-called pocket wagons while the driver accompanies the truck in a specific wagon and can have the statutory break.¹⁷⁰ Table 2 - 7 gives an overview of the possible classification approaches of CT concepts.

transport type	surface transport			sea port hinterland transport	
type of load carrier	piggyback transport			container transport	
	roll-on/roll-off	semi-trailer	swap-body	land container	overseas container
transshipment type	horizontal transshipment	vertical transshipment			
accompaniment	accompanied transport	unaccompanied transport			

Table 2 - 7: Systematisation of CT.¹⁷¹

A multiplicity of actors accomplishes the different CT services. In comparison with unimodal road transport, more actors are involved in the service production process. The diversity of CT actors increases the complexity of service production and must be considered for the integration of CT into SC concepts.

¹⁶⁵ cf. Cargobeamer (2011b). The conversion of a swap body or semitrailer costs approximately 5000 Euro and reduces the loading capacity. cf. Cargobeamer (2011a).

¹⁶⁶ cf. VÖV (2008), p. 34.

¹⁶⁷ cf. Ibid., p. 34. For instance the ACTS and the Modahlohr system.

¹⁶⁸ cf. UIRR (2011). The most common load carriers in the CT are the standardised swap body, class A (principally 13.6 m) and C (7.15 m, 7.45 m or 7.82 m), the ISO container of 20' (6.1 m), 30' (9.15 m) and 40' (12.2 m) as well as cranable semi-trailers (13.6 m).

¹⁶⁹ cf. Seidelmann (2010), pp. 29; Stölzle et al. (2008).

¹⁷⁰ cf. Seidelmann (2010), pp. 29. VÖV (2008), pp. 42.

¹⁷¹ cf. Böse et al. (2000).

2.2.2.3 Diversity of CT Actors

The production of CT services is accomplished by a multiplicity of legally and economically independent actors providing an overall marketable service.

Primary CT Actors

The primary actors of CT production are directly involved in the material and information flow processes.

Manufacturers and retailers are the shippers and principals of cargo transport. Many shippers charge 3PLs with the transport from a defined pick-up point to a destination point.¹⁷² 3PLs increasingly accomplish the entire logistics fulfilment independently and on its own responsibility.¹⁷³ The share of outsourced logistics and transport activities grows, but there are still many shippers with their own transport departments and capacities.¹⁷⁴ In many cases, manufacturers are also the brand owners. Separately or together with the retailing companies, they advertise their products. Often, this advertisement includes promises not only regarding the product quality, but also regarding availability and costs. Manufacturers act as the source of the flow of goods in the SC. Depending on the production concept, the manufacturer provides certain quantities of goods in certain time periods to be picked up by the carrier. The retailer acts as the sink for the flow of goods. The retailer passes the end customers' demand and orders certain goods.

The core competencies of 3PLs are transport (carriers) and warehousing services, but they also offer more complex value-adding services. Thus, 3PLs are often deeply integrated into the principle's value-adding processes. In contrast to *fourth party logistics providers* (4PLs), 3PLs provide their own assets, such as trucks, transshipment or warehouse capacities and knowhow. 4PLs focus on the coordination of the logistics service in one company or for an entire SC. 4PLs only provide knowhow and personnel, but do not own assets.¹⁷⁵

Carriers or freight forwarders (e.g., road carriers, rail carriers, shipping companies, air cargo carriers) accomplish mode-specific transport services on their own responsibility. The carriers are assigned by shippers, 3PLs or CT operators. Small and medium

¹⁷² cf. Gudehus (2005), pp. 970.

¹⁷³ cf. Sheffi (1990); Forslund (2009), Klaas-Wissing et al. (2010), Peters (2010).

¹⁷⁴ cf. Stölzle et al. (2011), p.72.

¹⁷⁵ For details on the 4PL concept and the meaning for the performance-oriented CT integration into SC concepts see section 3.3.

sized shippers usually do not influence the carriers transport mode choice. Thus, 3PLs are usually not bound to a specific transport carrier.¹⁷⁶ Big shippers with own transport capacities also demand CT services themselves. These shippers furthermore, transfer their sustainability strategies to the commissioned 3PL and determine the transport mode. They force 3PLs to increase the share of rail transport. Thus, shippers directly and indirectly demand CT services.

Road carriers accomplish the pre- and ongoing haulage in CT. A shipper or a 3PL assign the road carrier with the transport service in a certain time and for certain costs. In most cases, the road carrier can autonomously decide whether to use a CT service or fulfil the transport via unimodal road transport. Furthermore, road carriers are assigned by CT operators and offered door-to-door-services.¹⁷⁷

Rail carriers provide transport services via rail. They use rail infrastructure capacities, such as trackage and rail ports. Rail carriers require knowledge of rail transport specifics, such as electrical systems, track gauges and clearance diagrams as well as braking and security distances.¹⁷⁸ *Tractioners* provide the locomotives and the personnel for the train's drive. Usually, the rail carrier is the tractioner, too. Often rail carriers offer wagons for rental and corresponding services, such as maintenance and cleaning. Increasingly, rail carriers offer comprehensive logistics services to their customers.¹⁷⁹

Terminal operators offer transshipment services at the interface between carriers. Sometimes they offer additional services, such as warehousing, packaging and distribution services, repair, maintenance and wagon or load carrier rental.¹⁸⁰ Often, terminals are held by associations founded by CT actors.¹⁸¹

CT operators act as the interface between 3PLs, road and rail carriers, shippers and infrastructure operators and authorities. They purchase trains or part-trains from rail carriers and, to some extent, separate the traction service. CT operators provide complete transport services between consignment and receiving terminals. They, furthermore, offer door-to-door services for freight forwarders, 3PLs or shippers.¹⁸² CT operators take the risk for the utilisation of trains' capacities. Often, they offer further services, e.g., the provision of wagons, the physical handling and loading as well as

¹⁷⁶ cf. Bendul et al. (2009); Janz (2003), p. 15;.

¹⁷⁷ cf. VÖV (2008).

¹⁷⁸ cf. Hoffmann (2007), p. 71.

¹⁷⁹ cf. VÖV (2008).

¹⁸⁰ cf. Ibid.; Hoffmann (2007), pp. 24.

¹⁸¹ For instance DUSS (Deutsche Umschlagsgesellschaft Schiene-Strasse GmbH; www.duss-terminal.de).

¹⁸² cf. UIC (2010), pp. 47.

handling of the accompanying information such as delivery notes and customs documents.

Secondary CT Actors

The secondary actors of CT production are not directly involved in the material and information flow processes. They provide infrastructure, additional services and transport equipment.

Infrastructure operators and authorities provide the essential transport infrastructure (e.g., waterways, railways). Operating companies for roads plan, build and operate the road network in coordination with specific ministries. The EU claims that railway infrastructure operators must be legally independent from rail operations.¹⁸³ The aim of this separation is to grant transparent and neutral access to train paths for all interested rail carriers. Train paths can be understood as easements to the rail infrastructure, thereby enabling transport services. The infrastructure operator is responsible for the construction, maintenance and operation of the infrastructure. This includes process control and safety technique maintenance and repair as well as the development of train schedules. Furthermore, the infrastructure operator can be in charge of marketing railway lines.¹⁸⁴

In Germany, the infrastructure network is managed by the *DB Netz AG*. The *DB Station&Service AG* is reliable for the construction, maintenance and operation of stations and railports. Train path management is a central task of these organisations. Following payment, the train paths are assigned for a certain period of time. Germany has been criticised by the European Union, which claimed that market access to train paths free from discrimination is not possible, since the *DB AG* is both the rail carrier and infrastructure operator. The maintenance and operation of the railway network is supposed to be financed by the train path fees of specific trains. The stations are financed by station fees, to be paid for train stops at specific rail stations. In Germany, some tracks are not owned by the Deutsche Bah AG, e.g., between Elbe River and Weser River. Here, the owners and operators are reliable for maintenance.¹⁸⁵

¹⁸³ cf. the passed guideline 91/440 from July 7, 1991 for the development of railway companies in the European Union (online available under: <http://eur-lex.europa.eu/Notice.do?mode=dbl&lang=en&ihtmlang=en&lng1=en,de&lng2=da,de,en,es,fi,fr,it,nl,pt,sv,&val=241707.cs&page=>)

¹⁸⁴ cf. Polzin (1999), pp. 96.

¹⁸⁵ cf. Weserbahn (2011).

The *Swiss Train Path Ltd* or *trasse.ch*¹⁸⁶ is the train path allocation authority for the Swiss Federal Railways (SBB), the BLS AG and the Südostbahn AG (SOB) [Swiss South-Eastern Railway]. In Switzerland, the outsourcing of the train path allocation to a legal independent decision making body is a prerequisite for reaching fair competition on rail. In cooperation with rail carriers, the infrastructure operator *trasse.ch* is also reliable for timetable development.

There are additional service providers, for instance, for *IT services, cleaning services or renting wagons and locomotives*. Special wagons, such as for the transport of hazardous goods, are often owned by the shippers themselves. For instance, the Transwaggon group owns 1800 flat wagons and 10,200 covered wagons for long-term and short-term rental.¹⁸⁷ The VTG AG owns more than 50,000 wagons with more than 1000 wagon types for rent.¹⁸⁸ Both companies also offer additional rail logistics and transport services. The availability of wagons and locomotives is central to the constant flow of goods. In 2008, before the economic crisis, the capacities for construction were used to the full. However, even after the crisis there is a huge demand for the latest wagons.¹⁸⁹ This includes the so-called '*whispering brakes*', a special, noise-reduced brake type, and the reduction of infrastructure deterioration.¹⁹⁰ Thus, the manufacturers of wagons, locomotives and handling equipment such as cranes and reachstackers are important for a SC including CT.

An additional important actor is the *transport policy*. The national and European transport policy significantly influences the environmental factors for CT actors. Details on the impact of transport policy on CT integration into SC concepts are separately discussed in section 2.2.3.2.

Each SC actor accomplishes different processes. The following section introduces the number of partial processes and the structure of CT concepts.

¹⁸⁶ <http://www.trasse.ch/>.

¹⁸⁷ cf. Transwaggon (2011).

¹⁸⁸ cf. VTG (2011).

¹⁸⁹ cf. Stölzle et al. (2008); Weserems (2010).

¹⁹⁰ cf. DBAG (2011); Heister (2005); N.N. (2011b). Locomotive manufacturer must provide technical solutions for the raising mineral oil prices, for instance hybrid-locomotives and diesel-locomotives for the new transport relations without electric systems, such as the connection between China and Europe. cf. Riedl (2011), p. 46

2.2.2.4 Processes and Structure of CT Services

This section provides an overview of the material and information flow processes in CT concepts. Commonly, in comparison with unimodal road transport, CT processes seem to be much more complicated and less flexible, especially since unimodal road transport requires neither transshipment processes nor siding tracks.

CT concepts can, independent of the type of carrier, be subdivided into five main processes.

- (1) Pre-haulage by road transport (collection),
- (2) Transshipment to a consignment terminal,
- (3) Main haulage in a rail, inland or seagoing vessel,
- (4) Transshipment to a receiving terminal and
- (5) Ongoing haulage by road transport (distribution).¹⁹¹

These CT processes are usually part of a cross-company SC.

Figure 2 - 7 illustrates the material and information flow processes in more detail by means of an example of a global SC.

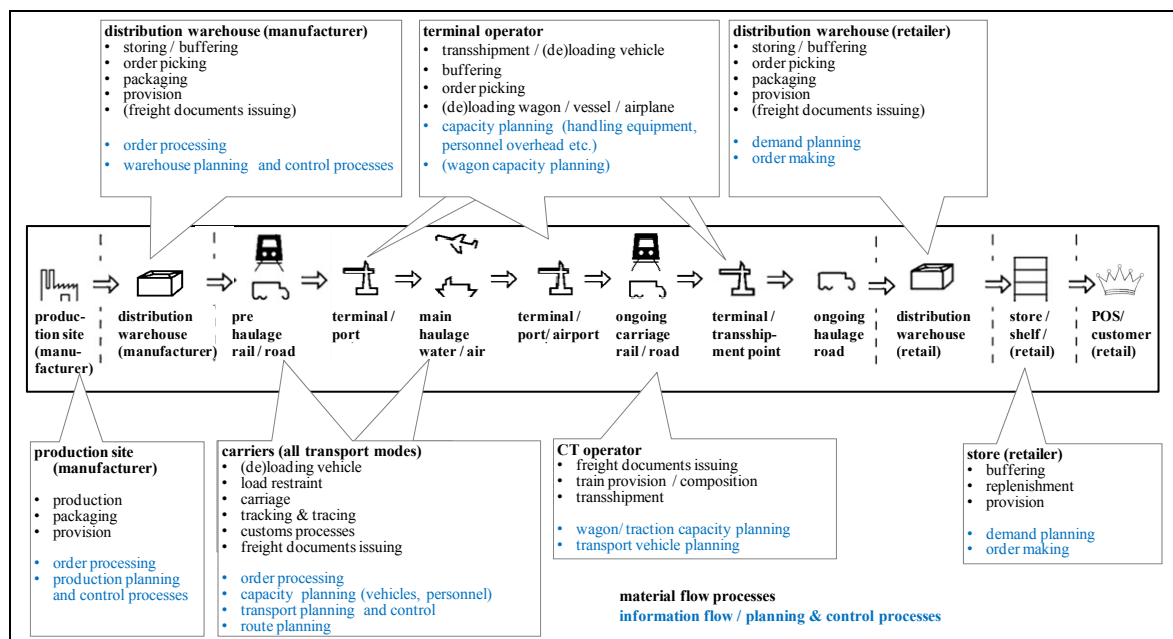


Figure 2 - 7: Schematic depiction of CT material (black) and information flow and additional planning and control processes (blue).¹⁹²

¹⁹¹ cf. Polzin (1999), p. 90 f.

¹⁹² Own illustration.

The physical transport processes (black) are accompanied by information flows, which require several planning and control processes (blue). Information includes shipment-specific delivery documents, tracking and tracing information, temperature regulations or corresponding monitoring information.

The *manufacturer* stores, picks, packages and provides the produced goods for carriage. Depending on the specific SC concept, the goods are stored in a warehouse for a certain time period and provided here. Freight documents are issued by the shipper, carrier or CT operator. *Carriers* of all transport modes load and deload the goods and transport them to their destinations. Carriers sometimes accomplish further activities such as tracking and tracing, customs processes or freight document issuing. The *terminal operator* uses cranes or mobile handling equipment for the transshipment, loading and unloading processes. If necessary, the goods are buffered and picked according to customer orders. The *CT operator* provides transport capacities for the main haulage (train, plane and vessel), transshipment processes, train composition and trackage. The DC of the retailer stores and buffers the transported goods for onward transport to the *store*. In the DC, goods are specifically picked and provided for transport to stores. The carriage to the store can be accomplished by CT, too (not depicted in the figure). In the store, the goods are buffered and shelves are replenished.

For all actors, *information* about orders and order forecasts are central for planning for instance equipment, vehicles, personnel and overheads. The retailer has a demand planning process on which it bases the order making process. These orders are processed by the manufacturer. The shipper or corresponding 3PL initiates the transport of goods.

A multiplicity of CT actors integrates a multiplicity of partial activities for CT service production. For only a few of these activities, there is an existing market. The partial CT services must be offered in total to the demanders (shippers, 3PLs), for instance in the form of terminal-to-terminal or door-to-door transport.¹⁹³

As in any service production, CT services are produced in two steps. Demand and service production usually take place simultaneously. This means for any CT service offers there must be a concrete demand. The shipper must provide information about

¹⁹³ Hoffmann (2009) provided an overview on different partial services according to provider and demander. cf. Hoffmann Hoffmann (2007), pp. 173.

the specific demand to initiate the disposition for the pre- and ongoing haulage and for the main haulage. Terminal capacities must be reserved. Furthermore, information on the irregularities, tracking and tracing, advice and invoicing must be provided.¹⁹⁴ The service character of CT is discussed in depth in the following section.

2.2.2.5 Service Character of CT Services

This section addresses the service character of CT services. The service character is a central aspect of the performance-oriented integration of CT into SC concepts. The integration of the shipper as the external factor complicates CT service production and thus, increases the need to align the CT concept and the SC concept.

Service production is a two-stage process. In the first stage, the so-called *pre-combination* builds up the *performance potential*. The CT service provider, usually the CT operator, bundles internal input parameters and generates a marketable service. This means that the CT operator must hold sufficient capacities of transport vehicles, terminals, personnel, train paths, overheads and knowhow before offering the CT service on the market.¹⁹⁵

In the second stage, the *end combination* complements and concretises the performance potential by adding further internal and external production factors. Service production takes place when there is specific demand for the CT service.¹⁹⁶ Thus, the demand is the initiator of service production.¹⁹⁷ For instance, a 3PL places an order with a certain shipper for the terminal-to-terminal transport to the CT operator at a certain time point. The CT operator accepts the order and initiates the end combination of production factors. This means that the shipment is received at the terminal, carried to the destination terminal and, finally, handed over to the 3PL or the shipper.

The production of CT services is characterised by immateriality.¹⁹⁸ Neither the performance potential nor capability is storable or tangible. Owing to the immateriality and synchronicity of production and demand CT services are unique.¹⁹⁹ These characteristics of CT services mean that the evaluation of the characteristics of transport

¹⁹⁴ cf. Ibid., pp. 22.

¹⁹⁵ cf. Bendul (2009).

¹⁹⁶ cf. Corsten et al. (1992), pp. 180.

¹⁹⁷ cf. Stuhlmann (2000), pp. 97.

¹⁹⁸ cf. Corsten et al. (1992), pp. 180.

¹⁹⁹ cf. Hoffmann (2007), p. 55.

services is impossible at the forefront of service production.

Transport services are often standardised. Carriers can realise economies of scale by meeting the requirements of several similar shippers from different industries. However, these service offers also include customised components. For instance, the usage of specific equipment and implementation of individualised processes (e.g., for temperature-controlled transport) enhances the standard service. The accomplishment of the transport service becomes obvious by the higher price of the transported good.

Next to these inherent characteristics, the complexity of CT is increased further by the external factors introduced in the following section.

2.2.3 External Factors Increasing the Complexity of CT

CT is strongly influenced by factors that cannot or can only be slightly influenced by the involved actors. The development of CT services regarding processes, technologies and business models is driven by a number of external factors and stakeholders.

As shown in section 2.1.1, *shippers* have high performance requirements in terms of flexibility, speed, quality and reliability to meet the end customer's demand. The CT actors have to deal with strong fluctuations in demand and unmatched relations. These factors complicate the capacity management and cause high attendance costs.

Legislature also influences CT, especially transport policy. Here, modal shift and subsidy policies, regulation policy, traffic-specific taxes and duties, infrastructure and technology policy as well as the activities regarding international harmonisation and standards must be taken into consideration.

Finally, the section discusses the *competitive situation with unimodal road transport*, which challenges the providers of CT services. CT requires specific investment in handling equipment, time quotas for additional handling processes and an increased coordination effort. At the same time, switching barriers back to unimodal road transport are very low.

2.2.3.1 Changing Shippers' Performance Requirements Challenging CT Services

This section addresses the meaning of the shipper's performance requirements on the production of CT. It resumes the aspects presented in section 2.1 and interprets the

general challenges for SCs including CT.

Shippers require customised logistics and transport services reflecting their demanding procurement, production and distribution concepts. This includes value-added services as well as transport-specific services, such the provision of tracking and tracing information, customs clearance and insurance services.²⁰⁰ Among the quality criteria, flexibility, speed and reliability are shippers' central SCP requirements.²⁰¹ Owing to the direct competitive situation with road transport, the market-oriented price of the CT service is the central decision criterion for shippers.²⁰²

The *customisation and flexibility* of CT services requires a coordination of CT actors and an alignment of CT processes, for instance to deal with short-term changes in time windows or fluctuations in transport quantities.

In 2011, an online market screening showed that CT does not meet shippers' expectations.²⁰³ This survey analysed shippers' expectations and opinions about CT, but not the performance of CT specifically. It showed that CT actors have to strengthen trust in CT performance and improve CT image. Table 2 - 8 compares the shippers' expectations on different performance criteria and the compliance on a scale from 1 to 15 (1 for the highest meaning of the performance criterion and 15 for the lowest meaning). The table shows that reliability regarding time, predictability and price are the most important factors regarding the expectations of CT services. Distance to the terminal (rank 10), the offer of tracking and tracing services (rank 9) and short lead times (rank 8) were rated with the lowest values. The comparison with the compliance of specific performance criteria shows significant differences between the expectations of shippers and the compliance of the CT service. It turns out that especially for central decision criteria such as price (difference -2) and late booking (difference -4) the difference is comparably low. As shown above for integration into SC concepts, flexibility and cost requirements are of central importance. However, the survey showed that CT often meets or exceeds SCP requirements regarding safety (+4), hazardous goods transport (+4), distance to the terminals (+6) and short transport times (difference +2). Reliability (-7), predictability (-5) and customer service (-11) are critical aspects. Here, the expectation and compliance values are

²⁰⁰ cf. Ibid., p. 68.

²⁰¹ cf. Evers et al. (2000), p. 28; 2000; Hoffmann (2007), p. 68.

²⁰² For details on the competitive situation between unimodal road and combined transport see section 2.2.3.3.

²⁰³ cf. Klotz (2011).

significantly different.

performance criteria	expectation (rank)	compliance (rank)
reliability (regular, punctual)	1	8
predictability	2	7
price	3	5
customer service	4	15
safety	5	1
late acceptance/booking	6	10
offer hazardous good'	7	3
short transport times	8	6
tracking and tracing	9	12
short distance to terminal	10	4

Table 2 - 8: Comparison of shippers' performance expectations and CT service compliance.²⁰⁴

According to the authors, the survey proves that CT has to increase service quality as well image.²⁰⁵

Next to the impact of shippers' performance requirements, CT service production is significantly influenced by transport policy.

2.2.3.2 Impact of Transport Policy on CT

The *legislator* is an important external factor on the production of CT services. On one hand, transport policy supports CT because of regulations against unimodal road transport (especially modal shift and regulation policy). On the other hand, transport policy incites the increasing share of combined and rail transport (especially through subsidy policies). Nevertheless, transport policy positively and negatively influences CT service production in terms of costs, speed and flexibility (especially through traffic-specific taxes and duties, technology and infrastructure policy, international harmonisation and standards).

Transport policy influencing CT takes place at all political levels – local, regional, national and EU. Responsibilities are shared subsidiarily.²⁰⁶ International transactions of EU policy are highly important for international CT. The main tasks are to promote the coordination of national policies and to coordinate actions in other fields such as target setting for emissions and standardisation.

National transport policies are key players in infrastructure development. This ap-

²⁰⁴ cf. Ibid.

²⁰⁵ cf. Ibid.

²⁰⁶ The highest political level acts as soon as the stated objectives cannot be reached by the lower levels.

plies to rail, road and waterway infrastructure as well as to interconnection points such as ports, terminals, logistics parks, maintenance and traffic management. Furthermore, the promotion of intermodality and innovations in transport depends on national governmental decisions.

Political instruments and measures provide the framework for the transport market, but also govern and control market developments. Economic reasons for regulatory policies are the high market share of governmental enterprises and specific shift policies to reduce external effects or balance capacity usage.

Modal Shift Policies and CT Promotion

The EU and several European governments promote the modal shift from road to rail or CT. The reasons are growing infrastructure shortages, rising transport volumes, sustainability and rising energy prices.

Transportation accounts for around 18% of total greenhouse gas emissions in Germany. About 41% can be attributed to goods traffic.²⁰⁷ Modal shift policies and promotion activities aim to reduce emissions and the environmental effects of unimodal road transport. The goal is to set up a sustainable and equitably utilised infrastructure network to avoid capacity bottlenecks for all transport modes. Until 2015, the main growth is expected for air and road transport, which produce the highest levels of emissions.²⁰⁸ Therefore, the shift to rail and waterways, which are more resource saving and cost-efficient, is in the central interest of current subsidy policies at an EU and federal level.

Today, European transport policy is nearly as expansive as are national transport policies. It contains business and social laws for traffic and transport safety as well as environmental protection. Both the EU and the individual states support rail and CT – even transnational – by means of different supporting programs.²⁰⁹ The main objective of these actions is the sustainable modal shift. The recent focus of subsidy policies has been infrastructure development and maintenance. However, investments in infrastructure in most EU countries are less than 1% of GDP (gross domestic product).²¹⁰ Furthermore, regulation policy is central for CT promotion.

²⁰⁷ cf. McKinsey & Company (2007), p. 11.

²⁰⁸ cf. BAFU (2010), Beco (2005); BMU (2011).

²⁰⁹ For instance, the support program 'Marco Polo' for intermodal transport. cf. EU (2011).

²¹⁰ cf. BMVBS (2009).

Regulation and CT Promotion Policy

Regulation policy controls competition within transport markets. Usually, regulations are transport mode-specific. Although there are different activities promoting CT, restrictions for unimodal road transport by regulation policy are the most efficient.

Regulations that confine unimodal road transport include the enforcement of more frequent road controls and driving bans at certain times or in urban areas.²¹¹ Furthermore, the introduction of the digital tachograph and regulations of driving and rest shift competitive advantages towards CT. In particular, these regulations influence the cost and price levels and thus, shift the competitive situation with the unimodal road transport for the benefit of CT.²¹²

Recently, the organisation of railway companies and their regulation regarding the fair conduct of inter- and intramodal competitive conditions have been discussed. However, the liberalisation of the railway system in Europe is partially incomplete and it has stagnated. Lately, the European Union has criticised the liberalisation progress in certain EU member states.²¹³

Moreover, the realisation of the interoperability of railway technology and safety systems, namely the ETCS, the European standard for railway safety systems, European driving licenses for locomotives and the implementation of environmental standards for traction vehicles and wagons are central aspects for the promotion of CT.²¹⁴

Traffic-specific Taxes, Duties and Subsidies

Traffic-specific taxes and duties affect the costs and competitive situation of CT actors. Therefore, tax harmonisation and subsidy policies within the European Union have strategic relevance. The different free trade agreements²¹⁵ and typical cross-national transport require harmonisation. Traffic-specific duties aim at an internalisa-

²¹¹ For instance, the introduction of environmental zones, speed limitations and sectoral driving bans.

²¹² cf. Stölzle et al. (2010)

²¹³ cf. N.N. (2011e). Germany, Spain and France were asked by the European Union to proceed with the liberalisation of the railways. In Germany, for example, the DB AG has been made to separate railway infrastructure and operations. In particular, the fact that the revenues of the infrastructure network are not entirely reinvested into the enhancement and maintenance of the railway network has been criticized.

²¹⁴ cf. Ojeda et al. (2002).

²¹⁵ cf. SECO (2011).

tion of resource usage, finance assurance and management of transport demands.

The latest topics are the EU emissions classification and the *internalisation of external costs* because of the change within the EU road tax directive. The internalisation of external costs aims to shift long-term costs to the causing transport actors. These include costs for accidents, infrastructure damage, noise and light emissions as well as effects on health, climate, nature and the landscape.²¹⁶ The internalisation of all costs, including external costs, corresponds to causative principles. In 2005 in Switzerland, the external costs caused by road transport reached CHF 8.1 Bio., whereas the external costs for rail transport for the same year were 0.5 Bio. The main parts were accident costs (CHF 2.0 Bio vs. 0.03 Bio), health costs (CHF 1.8 Bio vs. 0.1 Bio) and climate costs (CHF 0.9 Bio vs. 0.1 Bio).²¹⁷ This comparison of external costs shows that internalisation would have significantly increased the costs for unimodal road transport and shifted competitive advantages to CT.²¹⁸

The integrated cost and price management of CT actors has to consider the rising costs for taxes and duties. This is necessary to reach the required level of transparency and to meet shippers' performance requirements. This means that the toll systems of all the crossed countries and the prospective developments of these systems must be taken into consideration for the integration of CT. Uncertainties in transport policy,²¹⁹ such as the '*Alps transit exchange*' – expected for the time after 2020 – may negatively impact CT integration because of necessary CT-specific investment.²²⁰

Subsidy policies for rail and water transport (for instance, for siding tracks, terminals, etc.) are often not clearly communicated and presented for easy understanding. Often, CT actors are poorly informed of the possibilities to profit from subsidies.²²¹ However, a subsidy to cover investment costs can significantly influence the investment decision.

The *subsidy policy for transalpine CT in Switzerland* during the economic crisis in 2008 and 2009 can serve as a positive example of incentivisation. While road transport providers offered services even below their differential costs, unaccompanied

²¹⁶ cf. BfS (2005).

²¹⁷ cf. Ibid.

²¹⁸ cf. Dahm (2011).

²¹⁹ cf. BAV (2011b), Bendul (2011).

²²⁰ cf. Stölzle et al. (2008); Stölzle et al. (2009).

²²¹ cf. Stölzle et al. (2008); Stölzle et al. (2009).

CT had to deal with an even greater decrease in transport volumes. To prevent the long-term return to unimodal road transport, the Swiss transport department decided to enhance subsidies per CT shipment within a time limit. This action affected the cost ratio between unimodal and CT in favour of CT and influenced shippers' decisions by affecting transport costs. These examples prove that a resilient transport policy and a planning and investment environment significantly influences the shift from unimodal road transport to CT.

However, subsidies for shipments can also shift the cost ratio between CT and unimodal road transport in favour of CT.²²²

For instance, in Switzerland, the government subsidises up to 50% of the construction costs of a CT terminal. In 2011, the Swiss government has subsidised each transalpine shipment 75 Euro. The CT operator also obtains up to 1900 Euro per transalpine train. The amount applies to shipments from and to Italy and depends on the source and destination terminals.²²³ For each transalpine shipment of the rolling road, the subsidy is 175 CHF. A train is subsidised by 3080 CHF.²²⁴ The subsidy for unaccompanied CT is paid in Euros, for the rolling road in Swiss Francs.

Infrastructure and Technology Policy

The availability of infrastructure is a central resource for all transport concepts. Recently, there have been infrastructure shortages on all carriers, where road shortages are most significant. Increasingly, practice and science claim that these shortages endanger frequent transport concepts and thus, flexible and lean SC concepts.

The government finances road, rail and waterway infrastructure by public means and toll returns. These services build the basis of infrastructure policy and result in an infrastructure network connecting consignees and 3PLs. All further infrastructure capacities such as siding tracks, handling areas and connections on company areas need to be provided by users.²²⁵

Infrastructure development and maintenance implies the construction of roads and railways considering *priorities with respect to capacity bottlenecks* as well as an in-

²²² For details see for instance Bendul (2011).

²²³ cf. BAV (2011a). There are different tariffs from Italy to either the Netherlands (a), France (b), Great Britain, Belgium or Luxembourg (c), Denmark, North Germany, Scandinavia (d), Rhine-, Ruhr-, Main-area (Germany) (e), South-West-Germany or Switzerland with an amount of up to 1900 Euro. For instance, for a CT from Antwerp, the Netherlands to Novara, Italy with 28 shipments (75 €*28) + 1600 € = 3700 € is paid.

²²⁴ cf. Ibid.

²²⁵ This is an important overlapping of infrastructure and subsidy policies.

crease in reinvestments to maintain these. Furthermore, the optimisation and coordination of construction sites is part of the infrastructure policy. In addition, *technology policy* supports the feasibility of automotive engineering in the context of vehicle heights, weights and lengths, which are often interconnected with infrastructure capacities. For instance, there is an intensive discussion on the introduction of so-called 'gigaliners'. Moreover, telematics systems give opportunities to control transport flows by the provision of traffic information and suitable actions for network users.

CT actors benefit from the European infrastructure extension project TEN-T. The so-called TEN-T (Trans-European Transport Network) spans all transport carriers and all regions of the European Union.²²⁶ By adding missing traffic connections and by remedying bottlenecks, the traffic and mobility of people and freight can be upgraded. In addition, the TEN-T includes technological projects such as the European satellite navigation system 'Galileo', the so-called maritime motorway²²⁷ and the European railway traffic management system.

In particular, the availability and allocation of the capacities of the commonly used resources (e.g., terminals, carriers) cause problems for CT.²²⁸ *Unbalanced capacities, particularly terminal capacities*, are often caused by insufficient subsidy policies. Shortages in terminal capacities especially affect transport time and thereby overall SCP. The distances for pre- and ongoing haulage to the central major terminals are very long. Experts here see in the dispatch of terminal capacities a major need for action.²²⁹ From a shipper's point of view, the rigid time windows and time schedules especially cause problems: exceedingly late or early delivery and pick up times can only seldom be realised. Hence, this means significant quality and flexibility disadvantages for the image of CT.

Figure 2 - 8 predicts the shortages in CT terminals expected until 2015 in Europe. According to Seidelmann (2010), an additional transshipment capacity of 3.4 Mio transport units per year is necessary.²³⁰

²²⁶ cf. EK (2005).

²²⁷ Also called the 'motorway of the sea' or 'traffic separation zone'.

²²⁸ cf. Clausen et al. (2006), p. 57.

²²⁹ cf. Cordes (2011).

²³⁰ cf. UIC (2010), p. 74.

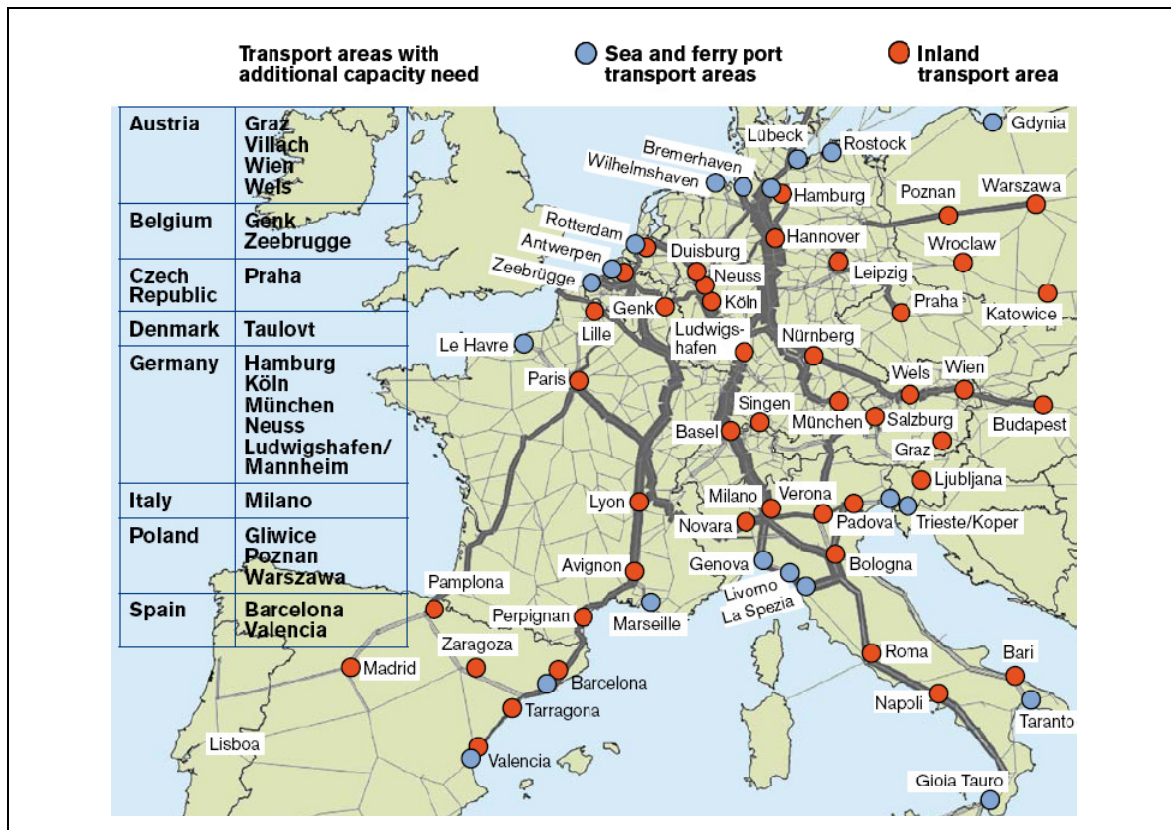


Figure 2 - 8: Overview of recent and expected CT terminal capacity shortages in Europe.²³¹

Unbalanced capacities result from the distortion of *unaligned subsidy policies*. There are several examples of economic projects that cannot survive without financial support. At a European level, this missing alignment leads to less efficient isolated solutions.²³²

Technology policy supports corporate activities in the field of CT by supporting technology development and innovation subsidies. In particular, in the field of innovation and new technologies, a smooth transition of corporate activities, processes and actors must be assured by the introduction of technological standards. The meaning of harmonisation and standardisation processes is discussed in the following section.

²³¹

cf. Ibid., p. 75.

²³²

cf. Frindik (2004), Stölzle et al. (2008). For instance, in France the innovative technological solution of the so-called 'Modalohr' system was introduced. This system allows lateral truck loading by the panning of wagon bottoms. The time-consuming frontal loading of the train can be avoided. Furthermore, the traction unit and the trailer can be independently transported. Thus, the piggyback transport and rolling road transport concepts can be combined. Owing to this innovative loading, there are specific requirements on the terminal layout and technique. Thus, these terminals require increased investments in comparison with the classical technique, but increase flexibility and operating costs. For instance, the transport units can be (de)loaded separately and at different terminals. The combination of the rolling road systems of France and the surrounding countries (e.g., Germany, Switzerland and Austria) would be sensible under network aspects. However, a combination with the classical terminal is not possible and cannot be accomplished without the specific investment in terminals and rolling stock.

International Harmonisation and Standards

International harmonisation and standards are central aspects for the production of cross-border CT services. In practice, international policies are only applicable in air and sea transport, whereas all other directives and implementation guidelines are substituted by EU policies.

For instance, there are standardisation activities in Europe regarding environmental standards for *traction vehicles and wagons*, general *tax harmonisation* within the EU and the European-wide harmonisation of *track prices*.²³³

Technical *system differences* challenge the management of SCs including CT. In particular, border-crossing transport faces problems caused by different types of loading units, wagons and locomotives as well as handling equipment. Furthermore, *different transshipment technologies* and the *reducing number of railway side tracks* restrict the net-ability of CT.²³⁴

Recently, European transport policy has focused on the *standardisation of electrical systems, railway language, track gauges and clearance diagrams* as well as on the dimensions of trains and trucks, load carriers and pallets. Recently, different train lengths have caused significant capacity losses for international rail and CT transport.²³⁵ Thus, there are activities to unify the train length to 750 m. In Germany, the maximum freight train length is 700 m.²³⁶ In Switzerland, the train length is principally 750 m²³⁷ whereas in Italy it is only 550 m.²³⁸ Thus, transnational CT and rail transport services between Germany, Switzerland and Austria cannot use capacities to the full.²³⁹ Thus, there have been recent efforts to standardise the train lengths on European freight transport corridors from North to South to 750 m.²⁴⁰ This additional time and costs cause significant competitive disadvantages for CT and rail transport in comparison with unimodal road transport.

Scientific studies and practical tests have been carried out to check the applicability of trains 1000 m long to increase the relation capacities. In 2009, the first tests were

²³³ cf. Klotz (2011).

²³⁴ cf. Böse et al. (2000), p. 279; Hoffmann (2007), p. 72.

²³⁵ cf. Siegmann (2011a); Siegmann (2011b).

²³⁶ cf. Fiedler (2005), p. 22.

²³⁷ relation specific its only 600 m,

²³⁸ cf. N.N. (2004b), p. 9.

²³⁹ cf. Wagner et al. (1999), p. 39; Consultants et al. (2004), pp. 46.

²⁴⁰ There are comparable capacity losses in East–West relations. In France, the maximum train length is 750 m. In Spain, it is only 450 m. The shorter siding tracks also cause additional shunting effort for the separation and joining of trains. Train rebuilding as well as regauging at the French–Spanish border (from normal to broad gauge) takes two to three hours. cf. Siegmann (2011a).

accomplished on the '*Betuweroute*' between Rotterdam, the Netherlands, and Oberhausen, Germany.²⁴¹

As shown, transport policy significantly influences the time-, space-, flexibility-, reliability and cost-oriented performance of CT services and thus, influences the competitive situation between CT and unimodal road transport. This competitive situation is clarified in the following section.

2.2.3.3 Competitive Situation of CT and Unimodal Road Transport

There is fierce competition between CT and unimodal road transport. The different levels of efficiency resulting from the inherent advantages and disadvantages of the carriers are central to the competitiveness of CT. Despite recent sustainability, energy shortages and green logistics considerations, costs remain the central selection criterion for transport carrier choice. Furthermore, the goods' and shipments' structures (type, size, quantity, frequency, lead time) as well as the available capacities of transport vehicles and load carriers are relevant decision criteria.²⁴²

The additional handling processes and coordination and planning activities cause cost disadvantages for CT in comparison with unimodal road transport. In particular, transshipment costs are step-fixed. Figure 2 - 9 gives a schematic overview of the cost situation of different intermodal transport concepts in comparison with unimodal road and rail transport. Figure (a) shows the steeper slope of the road transport curve in comparison with rail transport curve, whereas the fixed cost level of road transport is below the fixed cost level of rail transport. Thus, theoretically there is a certain transport distance where rail transport costs are below road transport costs. Figures (b) to (d) show further cost curves for multi-modal transport concepts. Further step-fixed costs are added for each transshipment process.

²⁴¹ cf. DBAG (2009).

²⁴² cf. Klotz (2011); Stölzle et al. (2008).

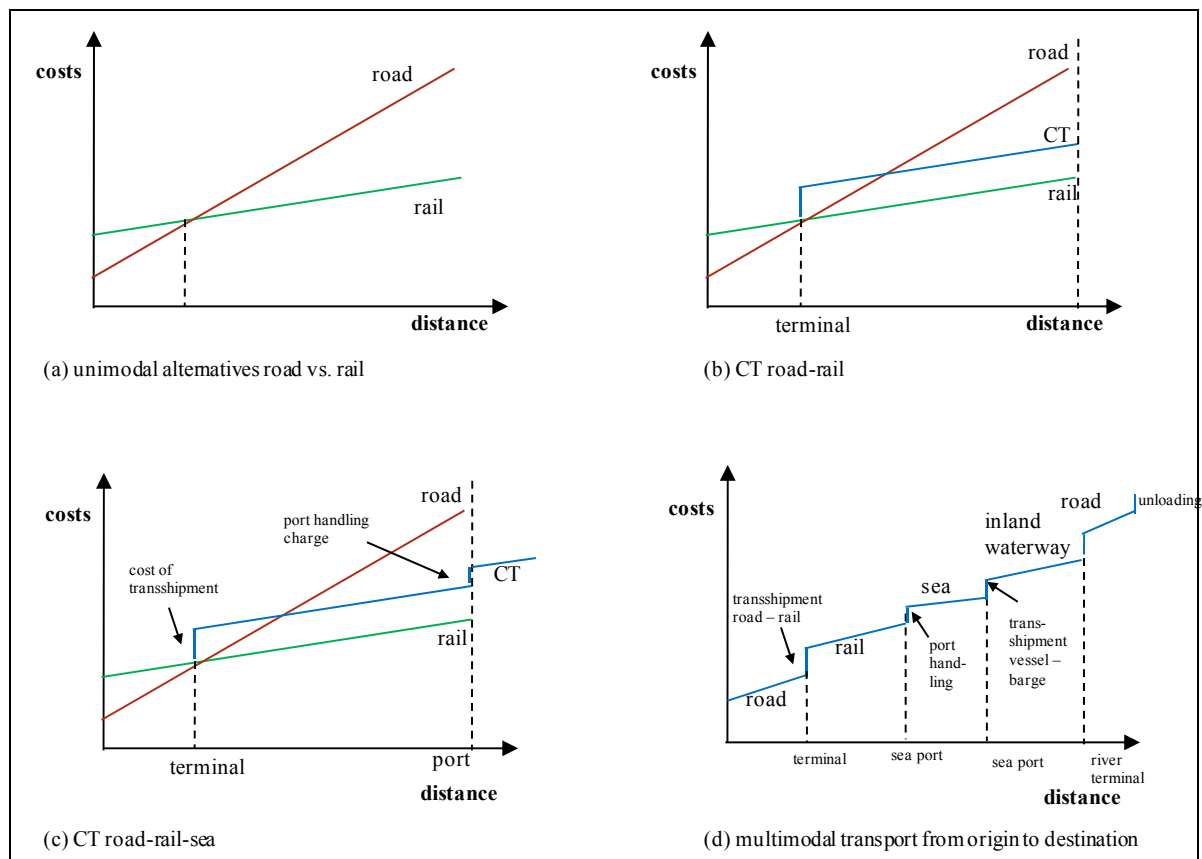


Figure 2 - 9: Schematic costs for unimodal, combined and multimodal road transport concepts.²⁴³

In particular, rail carriers, tractioners and terminal operators have to invest in cost-intensive vehicles and handling equipment. Thus, the standby costs of a CT service are significantly higher than those for unimodal road transport.

The resulting problems from these different cost structures became obvious during the economic crisis in 2009. The positive economic development until 2008 and increasing global transport volumes led to a massive enhancement of transport capacities for all transport modes. This development was reflected by a strong demand for vessels, rolling stock and trucks. Owing to long delivery times, these investments take effect only over time and capacities increase only gradually. Thus, in the economic crisis of 2009 a lowered demand for transport services met an increase in transport capacity. The result was a price collapse, which intensified competition in transport markets.

This situation has highlighted the price sensitivity of CT services. In summer 2009, road carriers offered their services at a price level not covering their marginal costs to sustain liquidity. Owing to the lower fixed costs and an often thin capital base, road

²⁴³ cf. Bonomyoung et al. (2001), p. 666.

carriers operated with massive allowances in the market. Since rail and CT actors could not offer discount prices, they experienced a significantly stronger decrease in transport volumes than did road carriers.²⁴⁴

Recently, most domestic transport and last-mile transport in SC concepts are accomplished by unimodal road transport. As shown in section 2.2.2.1, shippers have the prejudice that CT cannot meet SCP requirements and thus, prefer unimodal road transport. In addition to the cost and time aspects, the flexibility and the constant accompaniment of each shipment are important. A truck driver can change the transport route at any time and can always personally assure the goods' quality.²⁴⁵

2.2.4 Integrated Management of CT Concepts

The integrated management of CT concepts has specific challenges. These refer to the described internal and external framework conditions. To offer CT services to the market, integrated management is necessary. Resch (2008) identified three different types of CT concepts following the four dimensions of the business model proposed by Müller-Stewens and Lechner (2005).²⁴⁶

The authors distinguished between (1) the performance, (2) the value-adding, (3) the marketing and (4) the yield models. The model excels with its cross-company character and the possibility of consideration of different corporate divisions. Following the argumentation line of Müller-Stewens and Lechner (2005) the target of each business model is the enhancement of a shipper's benefits and the protection of competitive advantage.²⁴⁷ The model encompasses different perspectives and mutual relations between different perspectives. Resch (2008) applied the business model to the field of CT business models.²⁴⁸

To set up a CT service a central actor, such as the CT operator, arranges a group of actors, such as CT operators, rail carriers, road carriers and terminal operators, and ensures the availability of the necessary infrastructure resources. Either the group is individually arranged according to the performance requirements of a certain shipper or the group is arranged to offer a rather standardised CT service for different ship-

²⁴⁴ cf. Pfohl Stölzle et al. (2010).

²⁴⁵ cf. Stölzle et al. (2008).

²⁴⁶ cf. Müller-Stewens et al. (2005).

²⁴⁷ cf. Ibid., pp. 55.

²⁴⁸ cf. Resch (2009), p. 31; Ihde (2001).

pers.

In both cases, the group of actors requires the same *performance understanding*. Every actor needs different capabilities to handle the *determined shipment size* (full load, part load, mixed cargo) of a certain *physical condition* (universal or special cargo, such as liquid goods). The actors must agree on a *spatial structure of the transport service* (e.g., a standard service on regular relations or flexible services on different relations).²⁴⁹

Based on this common performance understanding a *mutual value-added model* is built. All CT actors agree on the *institutional structure* and configuration of the service production (vertically integrated, specialised and network configurations). The positions and tasks of all the CT actors for the service production are determined and documented. Furthermore, the CT actors determine *communication and coordination mechanisms* (coordination, hierarchical instructions, standardisation and market-oriented prices).²⁵⁰

The marketing model classifies the CT business model according to the configuration of the *integrated marketing process*. This means that different *modalities of business relations and thus, the stability of the relation* between shippers and providers of the CT concept are determined (long-term / short-term). CT actors have to agree on the *conservation of existing and setting up of new transport relations* aiming at the shipper's long-term obligation to the CT concept.²⁵¹

The yield model determines how CT actors equitably share costs and yields. For the offer of standardised services, actors agree on a *target customer group* (e.g., a specific company size, industry and region). An *appropriate cost and price management* (simple/complex, static/dynamic) is necessary to share costs as well as yields equitably. However, integrated approaches are not widely implemented in practice yet.²⁵²

Table 2 - 9 gives an overview of the four sub-models, the dimensions and the classification criteria for CT business models.

²⁴⁹ cf. Resch (2009), pp. 35.

²⁵⁰ cf. Ibid., pp. 37.

²⁵¹ cf. Ibid., pp. 33.

²⁵² cf. Ibid., pp. 40.

criteria	dimensions				
performance model	shipment size	mass good	full truck load	less than truck load	packaged goods
	physical condition	specialised		standard	
	spatial structure	rules relation	no rules - relation	rules network	no rules network
marketing model	customer group	small shippers		huge shippers	
	stability of CT configuration	long-term		short-term	
value-adding model	coordination mechanism	coordination	direct instruction	standardisation	market-oriented prices
	configuration	vertically integrated	specialised	network	
yield model	complexity	simple		differentiated	
	time horizon	static		dynamic	

Table 2 - 9: Classification criteria for CT business models.²⁵³

In practice, the business model differs regarding the configuration of the CT transport chain. Thus, for the identification of clear types the differentiation into vertically integrated, specialised and network configuration is the basis. Resch (2009) identified three generic CT business models: the (1) relation coordinator, (2) the relation integrator and (3) the network integrator.

The Relation Coordinator

The business model of the '*relation coordinator*' is characterised by the number of legal and economic independent actors, focusing on the production of specific partial services. All partial services are produced autonomously and are self-reliable.²⁵⁴ Commonly, a 3PL focusing on shippers' SCP requirements mediates between the CT actors and the shipper.²⁵⁵

By connecting the partial service, the 3PL can offer a comprehensive product to the shipper for one relation. Usually 3PLs operate for several shippers. Thus, this business model is focused on full truckloads of specific goods and industries to reach a high capacity utilisation.²⁵⁶

Owing to the high degree of independency, the actors use market-oriented prices for coordination.²⁵⁷ Often, this goes along with short-term business relationships.

²⁵³ Own illustration in accordance with Resch (2009), p. 43.

²⁵⁴ cf. Hoffmann (2007), p. 22.

²⁵⁵ cf. Trost (1999)1999, pp. 82; Pfohl (2003), pp. 7

²⁵⁶ cf. Brandenburg et al. (2008), p. 468.

²⁵⁷ cf. Hoffmann (2007), p. 47.

The Relation Integrator

The business model of the '*relation integrator*' is characterised by a vertically integrated CT chain. This integration results from one central actor, who initiates service production by its own transaction and/or by taking a long-term risk by agreeing to a high share of service production. An actor, offering such a '*one-shop solution*' is defined as an '*integrator*'.²⁵⁸ In this function, the integrator has intense contact with the shipper.²⁵⁹ Few processes, for instance the traction, are accomplished by additional independent actors. However, the integrated actor has full responsibility for capacity utilisation as well as the service level.²⁶⁰ It is even possible that an actor accomplishes all partial services on its own.

For instance, in 2002 *DB AG* repurchased *Schenker AG* as a 3PL and bought *Han-gartner AG* as a Swiss specialist of CT services between Skandinavia and Italy owning several terminals. *DB AG* was then able to offer a completely integrated CT service to shipping companies.²⁶¹ Nevertheless, all processes are accomplished by one company, and the service production is characterised by the division of labour. The challenges or process integration are thus still demanding.²⁶²

The high level of integration in this business model allows the usage of hierarchical coordination mechanisms because usually there is an asymmetric power distribution. Thus, service production is characterised by direct instructions and rules.²⁶³ In the case of economic and legal independent actors, steering by market mechanisms reflects the high bargaining power of the vertically integrated actor.²⁶⁴

The relation integrator focuses on big shippers and long-term business relationships to ensure high capacity utilisation.²⁶⁵ This is necessary because of the concentration of the availability costs and the high fixed cost share of only one actor.²⁶⁶ The relation integrator focuses on high, regular transport volumes²⁶⁷ and universal goods with

²⁵⁸ cf. Knorr (2005), p. 77; Brandenburg et al. (2008), p. 468.

²⁵⁹ cf. Knorr (2005), p. 77; Brandenburg et al. (2008), p. 468.

²⁶⁰ cf. Brandenburg et al. (2008), p. 468.

²⁶¹ cf. de Miroschedji (2002), p. 54.

²⁶² cf. Resch (2009), p. 48.

²⁶³ cf. de Miroschedji (2002), pp. 51

²⁶⁴ cf. Resch (2009), p. 249

²⁶⁵ cf. Benkenstein et al. (2007), pp. 51.

²⁶⁶ cf. Holderied (2005), p. 61, Gudehus (2005), 834 .

²⁶⁷ Thus, relation integrators focus on FTL.

high quality forecasts for spatial and temporal demand.²⁶⁸ These characteristics allow the setup of regular line transport for single shippers on specific relations.

One main advantage of the 'relation integrator' business model is the possibility to exclude competitors from the necessary infrastructure by the internalisation of activities. This operation of private terminals inhibits the free network access to the railway infrastructure for third parties.²⁶⁹

The Network Integrator

The '*network integrator*' business model stands for an organisational network of voluntarily cooperating actors. The network structure covers a geographic- and industry-specific market.

The setup of network structures has several advantages for the involved actors. First, the market power of small and medium-sized companies is increased even if they have no huge or regular transport volumes. Second, cooperation allows the bundling of transport volumes and thus, the realisation of a higher capacity utilisations.²⁷⁰ Third, it allows a significant cost reduction in comparison with entirely autonomous CT service production.²⁷¹

However, the network structure leads to strong dependencies among actors and requires mutual trust and intense communication and coordination mechanisms. Therefore, supporting I&C systems are required. Direct coordination and the steady exchange of views and ideas allow the harmonisation and alignment of partial activities.

The realisation of bundling effects allows the usage of block trains and the carriage of packaged goods. Therefore, specific transshipment points are required.²⁷² Service production in the network is comparably complex and thus, requires demanding planning and control systems. To reduce this complexity, processes are slightly standardised by the introduction of long-term framework contracts with shippers and a focus on standardised goods.

Recently, for instance, *DB AB* together with *Hellmann* and *Schenker* aimed to realise such a network under the name '*X-Pressnet*'.

²⁶⁸ cf. Brandenburg et al. (2008), p. 295.

²⁶⁹ cf. Knorr (2005), p. 468.

²⁷⁰ cf. Bachmann (2008), p. 20.

²⁷¹ cf. Bahrami (2001), pp. 52.

²⁷² cf. Brandenburg et al. (2008), p. 248; Pfohl et al. (2003), p. 9; Stölzle et al. (2011), p. 77.

In 2007, *X-Pressnet* was founded to develop a sophisticated network service for the transport of time-critical goods by rail. Starting from 2012, fast and punctual services (98% punctuality) working with delivery windows will be offered.²⁷³ However, the expected high costs will restrict the offer to time-critical and valuable products. Project partners are *Kombiverkehr GmbH & Co. KG* (CT operator), *DB Netz AG* (infrastructure operator), *DHL freight GmbH* (subsidiary of *DHL*; carrier offering unimodal road, rail and CT services for FTL, LTL and packaged good), *DUSS GmbH* (*Deutsche Umschlaggesellschaft Schiene-Strasse*; terminal operator), *Hellmann Worldwide Logistics* (road carrier, in 2010 bought by *DB AG*) and *DB Schenker Rail AG*.²⁷⁴

The introduced CT business models are generic. There is a multiplicity of further possible configurations and often CT concepts cannot be clearly allocated to one business model. In fact, most companies participate in more than one CT concept and thus, run more than one business model. However, for the thesis in hand a different classification focusing on the classification of material and information flows and the integration into different SC concepts is required. For this purpose, the performance profile of a CT concept is central, rather than the underlying business model (cf. section 3.4). Therefore, the following section develops a basic understanding of SCP and the associated key figures and performance indicators.

2.3 SCP Orientation – Consideration of Strategic and Operational Key Figures

SCP orientation means the consideration of strategic and operational key figures at a SC level. The target system of SCP allows SC actors to focus on both the impact of their own activities and a clear end customer orientation.²⁷⁵ SCP can evaluate the success of the information and material flow integration and the impact of the CT integration using financial key figures. Thus, SCP is chosen as the target system to evaluate the given problem of CT integration into SC concepts. According to Fabbe-Costes & Jahre (2008), SC integration can be interpreted as a basis for SCP manage-

²⁷³ cf. Vekehr (2011).

²⁷⁴ Planned rail relations are Hamburg-Munich, Hamburg-Nuremberg, Hamburg/Bremen/Hannover – Frankfurt/Basel, Hamburg/Bremen/Hannover – Nuremberg, Osnabrück/Hannover – Regensburg/Landshut. cf. Ibid.

²⁷⁵ cf. Karrer (2006), p. 125.

ment.²⁷⁶

In this section, the concept of SCP and the basics of a SCP management are briefly introduced to understand the meaning of a SCP-oriented integration of CT into SC concepts. The section's aim is to understand how SCP can be used as the SC-wide target system considering all the requirements and challenges of all SC and CT actors.

2.3.1 Fundamentals of Performance Orientation

SCP measurement focuses on the development and maintenance of measurement systems as well as the measurement and control of the SC. SCP management focuses on strategic and operative control functions in an integrated management approach.²⁷⁷ In this integrative function, SCP management acts as a bridge between corporate leadership and the performance system.²⁷⁸ Nevertheless, SCP management does not include comprehensive leadership, but rather it is limited to the specific application field that is being modelled by the included key figures and performance indicators.²⁷⁹

Performance measurement was introduced in the 1990s to overcome the problems of traditional key figure systems.²⁸⁰ Usually, these key figure systems are designed with regard to accounting needs, but cannot evaluate the operations of SCM or be used for strategic management purposes.²⁸¹

The current literature still lacks research in different fields of performance measurement.²⁸² For instance, there are open fields in terms of the conceptual development of performance measurement, new adaptation fields and the generalisation of the implementation of performance measurement. The performance-oriented CT integration

²⁷⁶ cf. Fabbe-Costes et al. (2008), pp. 131.

²⁷⁷ cf. Stölzle et al. (2004b).

²⁷⁸ cf. Karrer (2006), p. 4; Keebler (2001), p. 428. Based on these practical needs a completely new research field emerged in the early 1990s.

²⁷⁹ cf. Caplice et al. (1994), Cooper et al. (1997), p. 10. Part-processes of management, such as company policy and management development are thus, not influenced by the performance management.

²⁸⁰ Traditionally, systems of key figures have been oriented to companies' accounting systems. These systems of key figures are not capable of meeting the entire information demand of diversified and market-oriented organisations. In particular, the aggregation level, the short-term consideration period, delayed information availability, the lack of planning and strategy orientation and the disregard of external influencing parameters and stakeholders of these accounting oriented key figures have been criticised. See for instance Kaplan et al. (1992), p. 71; Hoffmann (2000), pp. 22; Hammer (2003), pp. 519; Müller-Stewens et al. (2005), pp. 697.

²⁸¹ cf. Gleich (2001), p. 11; Kaplan et al. (1992); Karrer (2006), p. 118; Lebas et al. (2002); Neely et al. (1995).

²⁸² cf. Karrer (2006), p. 120.

into SC concepts can be understood as a new application field. The thesis in hand examines the new application field and thus, a generalisation of the given implementation rules is developed.

Several authors have discussed the definition of 'performance'. The number of different performance definitions shows the need for a common performance understanding to reach a common goal of CT integration into SC concepts.²⁸³

The term '*performance*' implies that it is a ratio key figure that compares different input parameters.²⁸⁴ Stölzle & Karrer (2004b) comprehensively discuss the performance term joining operational and strategic aspects.²⁸⁵ To achieve this match the performance understanding is specified by the concepts of efficiency and effectiveness.²⁸⁶

Performance measurement includes both monetary and non-monetary key figures. Several empirical surveys have demonstrated the need for non-monetary information, such as customer satisfaction, productivity or innovation. Thus, performance measurement includes non-monetary key figures. For instance, the introduction of Total Quality Management led to an increased focus on internal process key figures, such as error rates, setup and lead times and product quality.²⁸⁷ Increasing competition and end customer orientation have also raised the focus on customer satisfaction, time to market or number of new products.²⁸⁸

Performance is defined by its two components of efficiency and effectiveness. The *efficiency and effectiveness orientation* implies that performance is no absolute performance category, but a ratio that compares different input parameters.²⁸⁹ Efficiency and effectiveness orientation aims at the integrated measurement of resource usage, of the value-adding process and of the company's achievement of objectives.²⁹⁰

²⁸³ For instance, production management follows the physical definition and interprets performance as the output as accomplish work unit per time unit. (cf. Küppler et al. (2004)); tightly connected with this understanding is the term of 'efficiency' - including a technical and economic component. Technical efficiency refers to the term of 'productivity'. It means the relation of real output and real input. cf. Corsten (2004), p. 43; Karrer (2006), p. 122. Based on this definition, economic efficiency means the evaluation of input and output by the ascription of costs and proceeds respectively with expense and revenues. cf. Ibid., p. 122; Gleich (2001), pp. 38. There are several more approaches for the measurement of efficiency. See for instance Pfohl (2010), p. 41. introducing the concept of social and ecological efficiency. The controlling unit usually interprets performance as a determinant for the costs or quantity components of proceeds.

²⁸⁴ cf. Lebas et al. (2002), pp. 34, 68, 82, Mentzer et al. (1991), p. 34; Neely et al. (1995), p. 240, 82; Reiner (2004), p. 227; Stölzle et al. (2004b), p. 227, 240; Seidl (2002), p. 29.

²⁸⁵ cf. Stölzle et al. (2004b), p. 68.

²⁸⁶ cf. Karrer (2006), p. 125; Neely et al. (1995), pp. 80.

²⁸⁷ cf. Karrer (2006); Barker (1995); p. 31.

²⁸⁸ cf. Karrer (2006), p. 131.

²⁸⁹ See for efficiency and effectiveness aspects of performance, e. g., Mentzer et al. (1991), p. 34; Neely et al. (1995); Lebas et al. (2002), p. 68; Stölzle et al. (2004b), p. 240; Seidl (2002), pp. 29.

²⁹⁰ cf. Caplice et al. (1994), p. 19; Karrer (2006), pp. 126.

Efficiency is concretised by two ratios: the degree of utilisation (*resource input*) and the degree of productivity (*value-adding process*).²⁹¹ Effectiveness orientation enhances the efficiency understanding by the aspect of target relativity in terms of the comparison of actual and planned results.²⁹² Effectiveness is defined as the ratio of effective input and planned output (*target achievement*). Thus, the outputs that are suitable for the main target achievement must be identified and the degree of achievement must be measured and adapted if necessary.²⁹³ Figure 2 - 10 visualises these considerations.

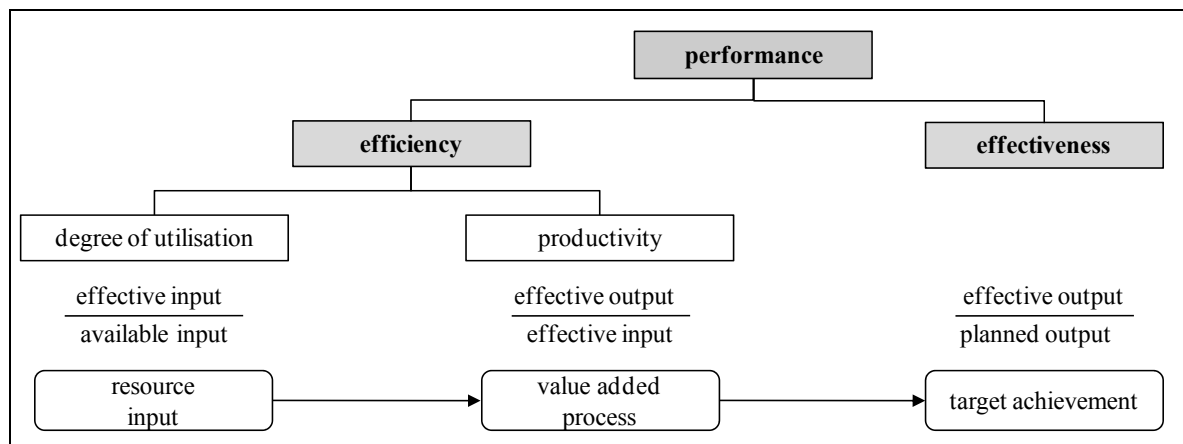


Figure 2 - 10: Efficiency and effectiveness dimensions of performance.²⁹⁴

Several authors have analysed different measurement types and quality criteria for key figures of performance operationalisation. Of the traditional quality criteria of *empirical measuring instruments*, such as validity, reliability and objectivity, the key figures and performance indicators included in the SCP target system must do justice to the following criteria:²⁹⁵

- Integration potential: The key figures support the cross-interface coordination and can be integrated into existing planning and control systems.
- Early indicator and forecast ability: The key figures support the recognition of changes. This allows early reactions and improves the calculation of trends.
- Aggregation ability: Key figures require an appropriate level of detail. A logical structure of the key figure system has to ensure both the aggregation and categorisation of key figures.

²⁹¹ cf. Ahn (2003), pp. 90; Gladen (2003), p. 30; Karrer (2006), p. 125.

²⁹² cf. Stölzle et al. (2004b), p. 240; Caplice et al. (1994), p. 19; Karrer (2006), pp. 126.

²⁹³ cf. Otto et al. (2002), p. 279; Gladen (2003), p. 132; Ahn (2003), p. 92; Karrer (2006), p. 126.

²⁹⁴ cf. Caplice et al. (1994), p. 19; Karrer (2006), p. 127.

²⁹⁵ See for comparable lists Caplice et al. (1994), p. 14; Delfmann et al. (2003), p. 44; Erdmann (2003), pp. 160.

- Incentive compatibility: The key figures support compliant behaviour. This means that they avoid unsolicited management effects or dysfunctional behaviour.²⁹⁶ Thus, each key figure must be clearly allocated to one scope of responsibility and be linked with specific incentive systems. This aspect includes that the key figure is suitable to reflect the company's value-oriented objectives.
- Profitability: It must be ensured that the benefits of a key figure's measurement exceed the costs of enquiry, analysis and evaluation.²⁹⁷
- Application orientation: The results of performance measurement must support the decision makers for the evaluation and selection of action alternatives. Whenever possible, the task of decision support should be based on the latest IT.

To transfer the performance term to the SC level several adaptations are necessary. The following section introduces the main ideas of performance understanding in a SC context.

2.3.2 Performance Understanding in a SC Context

Several authors have enhanced the general performance understanding and transferred it to the SC level. This section discusses the necessary adaptations and enhancements for transferring the performance definition from the corporate to the SC levels.

For instance, Karrer (2003a) suggested the enhancement of the performance understanding by the characteristics of *multidimensionality* as well as *future and potential orientation*.²⁹⁸

The *multidimensionality of SCP* is often put on one level with the consideration of non-monetary key figures in management control.²⁹⁹ This refers to the configuration of the balanced scorecard, differentiating between 'finance', 'customer', 'internal processes' and 'learning and development' as categories for the central key figures. Multidimensionality stands for the different categories of objectives influencing the term of performance. This corresponds to the target system of SCM. The SCP understand-

²⁹⁶ cf. Gladen (2003), p. 11.

²⁹⁷ cf. Karrer (2006), p. 132.

²⁹⁸ cf. Ibid., p. 132; Power (2005), pp. 196.

²⁹⁹ cf. Hoffmann (2000), p. 17; Schrank (2002), p. 69.

ing considers both formal targets and content targets to be relevant.³⁰⁰ The content targets must be ascribed by a certain value to do justice to the financial, formal targets. This provides a special challenge since the content targets do not only refer to the result of the value-adding processes, but also the development of competencies and (success) potential. These '*intangible assets*' often only indirectly affect financial performance indicators.³⁰¹

The *future and potential orientation* means that SCP is no punctual event. It describes to what extent a company is able to reach future objectives. For this purpose, a process-oriented performance understanding is suitable. It focuses on the current activities leading to future results for prospective performance. The focus of performance measurement is thereby shifted from period- and past-oriented performance indicators to early indicators and the identification of influencing variables.³⁰² The main challenges are the uncertainty about future action alternatives as well as the divergence of cause (recent activity) and effect (potential, prospective activity). To be more precise, in the field of SCM, future and potential orientation means the growing importance of the time and flexibility dimensions in the SCM target system.³⁰³

Impacted by the balanced scorecard,³⁰⁴ Karrer (2003a) also highlighted five necessary adaptations to the general performance understanding to transfer it to the SC context:

- (1) Balance of performance measurement,
- (2) Ability to reflect cause-and-effect relationships,
- (3) SC strategy connection,
- (4) User-oriented preparation and visualisation of metrics and
- (5) Process orientation.³⁰⁵

(1) The *balance of performance measurement* means the claim of SCP understanding for a balance between internal and external respectively integrated and cross-company integrated key figures. This means that it can be necessary to simplify the corporate performance measurement. Usually, the high level of detail is not necessary

³⁰⁰ cf. Gladen (2003), p. 31; Karrer (2006), p. 127.

³⁰¹ cf. Kaplan et al. (2004), p. 52; Müller-Stewens et al. (2005), p. 703.

³⁰² cf. Stölzle et al. (2004a), p. 174; Lebas et al. (2002), p. 72.

³⁰³ This shows publications on process-oriented time management and time base performance management, e.g. Karrer (2006), p. 129.

³⁰⁴ cf. Stölzle et al. (2002), pp. 75; Stölzle et al. (2001), p. 78.

³⁰⁵ cf. Karrer (2006), p. 127.

for the performance measurement of cross-company relationships.

(2) The *ability to reflect cause-and-effect relationships* means that the causal connections between the activities of single SC actors and the potential consequences for the entire SC must be reflected by SCP.³⁰⁶

(3) *SC strategy connection* means that performance orientation in a SC context must be aligned according to the SC strategy. This is a specific challenge, since often there is no common SC strategy.³⁰⁷ Usually, SC actors commonly choose SCM targets and thus, implicitly formulate and adapt SC strategy.³⁰⁸

(4) The *user-oriented preparation and visualisation of metrics must consider* the increasing number of recipients and increasing complexity of measurement subjects. The visualisation of the SC structure and relevant material and information flow processes is the basis to achieve a common understanding of the SC in general as well as SCP.³⁰⁹

(5) *Process orientation* is central for SCP measurement.³¹⁰ The transfer of logistics process thinking to performance measurement implies that the objectives, metrics and measures for SC control must consider not only the corporate and SC strategies, but also the SC processes. For this purpose, a bottleneck-oriented process analysis of the SC is recommended, which can be supported by specific methodologies and instruments.³¹¹ This leads to a countercurrent process and strategy orientation of performance measurement.

SCP Management

SCP management enhances the measurement aspect and includes the measurement and control of the integrated decision making following the development and maintenance of integrated measurement systems.

The objectives of SCP management are defined with a focus on the SCM concept. Aiming for the formal target of the increase in SC value, the content targets of the increase in end customer benefit, decrease in costs, realisation of time advantages and increase in quality are central.

³⁰⁶ cf. Keebler (2001), p. 430

³⁰⁷ cf. Stölzle et al. (2001), p. 144; Bacher (2004), p. 144 and the here referred authors.

³⁰⁸ In section 3.1 the development of SC strategies is comprehensively discussed.

³⁰⁹ cf. Bacher (2004), p. 175.

³¹⁰ cf. Karrer (2006), p. 143; Reiner (2004), p. 218. For the conception of process-oriented performance measurement in the telecommunication industry see Binder (2003), pp. 46.

³¹¹ cf. Karrer (2006), p. 143.

As shown in section 2.1.1, the target system of SCM is characterised by several interdependencies. Through the application of the SCP dimensions, the impact on the SCP management concept can be visualised. The *efficiency dimension* of performance is influenced by process efficiency and resource efficiency. This affects the cost situation of each SC actor. The *effectiveness dimension* focuses on the realisation of time advantages and increase in quality in the SC. These affect the increase of end customer benefit and the SC's market success. The *efficacy dimension* of SCP is shaped by the target of the increase in corporate value. Figure 2 - 11 visualises the relationships between the target dimensions.

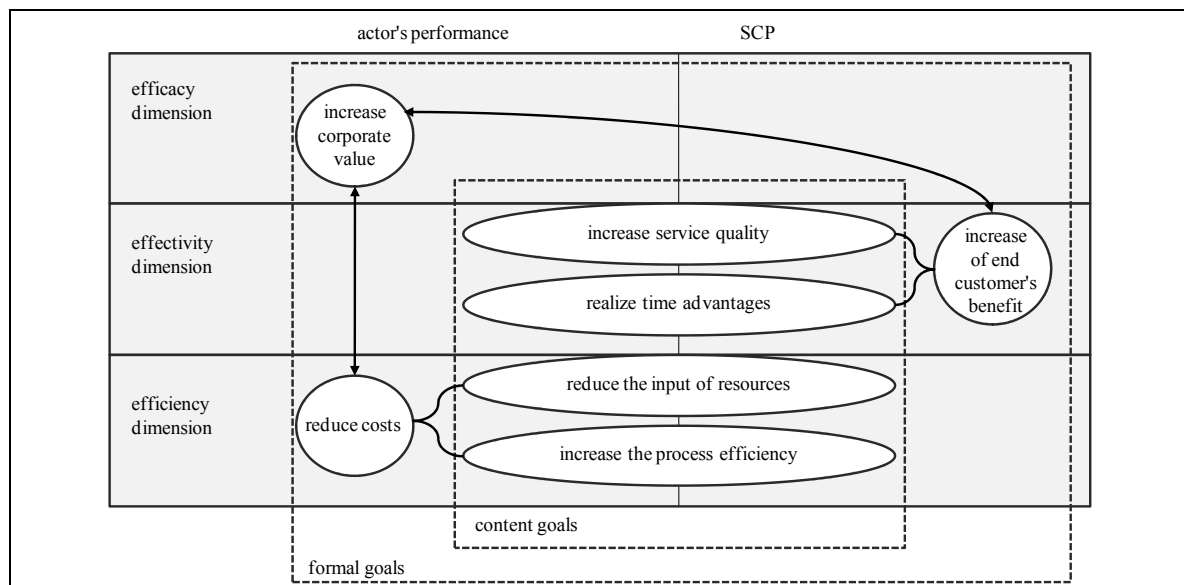


Figure 2 - 11: Characterisation and ideal cause-and-effect relationships between the targets of SCP management.³¹²

The central challenge of SCP management is the creation of an awareness of the validity and significance of these targets as well as connecting the cause-and-effect relationships.³¹³ In particular, the connections between cross-company and a company's internal targets are central. The content targets directly influence formal targets. These have to be coordinated among SC actors and analysed regarding their effect on market success, actor-specific costs and the increase in the value targets of actors.³¹⁴

Based on these considerations the following section shows that SCP is a suitable target system for the evaluation of the integration of CT into SC concepts.

³¹² cf. Ibid., p. 219.

³¹³ cf. Ibid., p. 218; Schary et al. (2001), p. 442. The authors argument that the cause-and-effect relationship and especially the effect direction of internal and external targets is often unknown.

³¹⁴ cf. Schönsleben et al. (2003), pp. 22.

2.3.3 Suitability of SCP as a Target System for the Integration of CT into SC Concepts

The considerations of the SCP measurement and management conceptions are important for solving the research problem in the thesis in hand.

SCP is a suitable target system for the evaluation of the effect of CT integration into a specific SC concept because of the inclusion of strategic and operational aspects as well as the consideration of value- and finance-oriented aspects.

The SCP as a target system reflects the multiplicity and variety of different actors in SCs including CT. The multidimensional performance understanding allows applying the target system for actors with different strategic and operative alignments. CT is characterised by an environment of high investment and thus, long planning horizons. The future and potential orientation of SCP reflects this. Furthermore, since the analysis of the potential of CT integration is central to the thesis in hand, the SCP concept seems to be appropriate.

This section briefly reviews the literature on performance understanding and performance measurement in the context of CT. The recent performance understanding in the context of CT serves as the basis for the development of suitable performance indicators to evaluate the integration of CT into SC concepts.

Meaning of Performance Orientation in the Context of CT Concepts

In practice, a central challenge of the cross-company performance measurement is the actors' *inhibition* to share confidential data.³¹⁵ According to Hoffmann (2006),³¹⁶ further challenges are the service and network character of CT. The immateriality of the CT service, the uniqueness of the service offer as well as the specific framework conditions of the single actors are central concerns. For a cross-company performance management, a SC-wide performance understanding is necessary.

In a first step, four different dimensions of performance measurement for CT services are introduced. Based on this, the challenge of the evaluation of partial and total CT services is discussed. Several performance indicators and application possibilities are exemplarily introduced.

³¹⁵ cf. Hoffmann (2007), p. 152, Weber (2002), pp. 113.

³¹⁶ cf. Hoffmann (2007), p. 152.

Dimensions for the Performance Measurement of CT Services

The literature states that the performance of CT services can be measured by four different performance dimensions: (1) potential dimension, (2) process dimension, (3) output dimension and (4) the effect/benefit dimension.

In the *potential dimension*, the performance of a CT concept is understood as a capability or the availability of resources for the fulfilment of a specific service. The performance potential of a CT concept can be measured by qualitative and quantitative indicators. Quantitative indicators include the number of locomotives, wagons or train paths. These indicators provide no information on the usage of the resources.³¹⁷ Thus, additional qualitative information for the evaluation of the potential is required, such as the width of the service portfolio and the knowhow of the employees.³¹⁸ This qualitative information can be gained by experienced employees and by consulting experienced third parties.³¹⁹

CT service production can be evaluated by the indicators of the *process dimension*.³²⁰ The shipper as the external factor of the CT service production is important for the process dimension.³²¹ The customers of CT services are not in the service production all the time, but sometimes. This means external factors, for instance CT actors, influence the measurement as well as the result.³²² The key figures for the *process dimension* are qualitative or quantitative. Quantitative key figures include the distance covered in kilometres. Qualitative key figures refer, for instance, to disposition services or the provision of traffic information. The operating times of the disposition system or the share of requested and provided traffic information can express this.

The *result- or output-oriented dimension* interprets the performance of CT concepts according to the realised shipments' space/time changes. These include the space/time change. The result can be measured by the quantity of transported goods over a certain distance in ton kilometres or by the number of transport containers per time unit.³²³

³¹⁷ cf. Pfohl (2010), p. 213. Thus, these key figures are supposed to be part of target and performance agreements, for instance in terms of quotients of as-is operating hours and the maximum operating hours.

³¹⁸ cf. Hoffmann (2007), p. 153.

³¹⁹ cf. Engelke (1997), p. 42.

³²⁰ cf. Reckenfelderbäumer (1995), pp. 34; Weber (2002), p. 65.

³²¹ cf. section 2.2.2.5 to the service character of CT services.

³²² cf. Hoffmann (2007), p. 155.

³²³ cf. Engelke (1997), 46.

The *effect- or outcome-oriented dimension defines the performance of a CT concept* as the level/degree of fulfilment of a certain CT task. This means performance is evaluated at a rather immaterial level. For instance, meeting the shipper's demand can be an indicator of the effect-oriented performance dimension.³²⁴ Owing to the immaterial character of the indicator, the evaluation is characterised by a high level of subjectivity. The evaluation is accomplished from a customer's perspective with regard to its own demand structures, the demand structures of its customers and the market and competitive situation.

The literature shows that next to the classification according to performance dimensions the performance of CT concepts is evaluated for different scopes. The chosen performance indicators can reflect either partial or total performance. However, for the thesis in hand performance indicators for the evaluation of the entire SC must be developed.

Measurement of the Total and Partial Performance of CT concepts

The production of CT services means the integration of several partial services (cf. section 2.2.2.4). Thus, the performance measurement can be accomplished at the level of partial and total services. Hoffmann (2006) suggested a consideration of the performance measurement of CT concepts at three main levels: the single actor level, the dyadic level and the network level (all CT actors). For the thesis in hand, this perspective must be enhanced to the SC level.

³²⁴ cf. Weber (2002), p. 64.

At the *single actor's level*, the performance measurement considers only the activities of one CT actor. The performance indicators can be classified according to the efficiency and effective dimensions as well as the strategic and operative indicators. For instance, the efficiency of a road carrier can be evaluated by the operative costs per truck (strategic dimension) or the truck's capacity utilisation for the pre- and ongoing haulage (operative dimension). These indicators do not allow any statements on the performance of the other CT actors, the integration of material and information flow processes or the entire SCP. Figure 2 - 9 gives an overview of the strategic and operative performance indicators at the actor's level for road carriers, terminal operators, rail carriers, CT operators and 3PLs.

strategic / operative performance indicators		indicators for strategic performance	indicators for operative performance
road carrier	efficiency	<ul style="list-style-type: none"> • average operative costs per truck • average personnel cost share per kilometre 	<ul style="list-style-type: none"> • capacity utilisation of trucks in pre and ongoing haulage
	internal effectiveness	<ul style="list-style-type: none"> • degree of flexibility • turnover per year 	<ul style="list-style-type: none"> • adherence to schedules per delivery • turnover per order
terminal operator	efficiency	<ul style="list-style-type: none"> • average capital commitment per crane • average capacity utilisation per transshipment facility 	<ul style="list-style-type: none"> • transshipment frequency per hour • buffer and storage space capacity
	internal effectiveness	<ul style="list-style-type: none"> • degree of flexibility (value-adding services) • increase in turnover by value-adding services 	<ul style="list-style-type: none"> • availability of transshipment capacities • lead times in terminal
rail carrier	efficiency	<ul style="list-style-type: none"> • average capacity utilisation of entire fleet 	<ul style="list-style-type: none"> • utilisation of train per order • number of trains per day
	internal effectiveness	<ul style="list-style-type: none"> • average adherence to schedules • market share [%] 	<ul style="list-style-type: none"> • adherence to schedules at the arrival at the destination terminal
CT operator	efficiency	<ul style="list-style-type: none"> • average utilisation of terminal-to-terminal services 	
	internal effectiveness	<ul style="list-style-type: none"> • number of offered block trains per week 	<ul style="list-style-type: none"> • booking deadline for customers [days]
3PL	efficiency	<ul style="list-style-type: none"> • average number of employees per order 	<ul style="list-style-type: none"> • number of employees per order • disposition time per order
	internal effectiveness	<ul style="list-style-type: none"> • degree of flexibility against shippers • turnover share of certain CT market segments 	<ul style="list-style-type: none"> • adherence to schedules at pickup and delivery

Table 2 - 10: Selected performance indicators at the actor's level.³²⁵

At the *'dyadic level'*, performance measurement focuses on the interface between two CT actors. As shown in section 2.1, SC actors often focus on dyadical relationships instead of taking an integrated SCM perspective. In CT chains, the focus on dyadical relationships is also common. For instance, the performance between a CT operator and a rail carrier can be measured by the degree of flexibility in the availability of specific wagons (strategic dimension) or waiting times at the terminal (operative dimen-

³²⁵ cf. Hoffmann (2007), p. 173.

sion). Figure 2 - 10 gives an overview of selected performance indicators for the production of CT services. These performance indicators are neither suitable to evaluate the performance of the entire CT concept nor to evaluate SCP.

strategic / operative performance indicators	indicators for strategic performance	indicators for operative performance
shipper - road carrier	<ul style="list-style-type: none"> • average loss ratio • degree of flexibility (e.g., regarding additional services, for instance container cleaning) 	adherence to schedules for collection of transported good
CT operator - terminal operator	<ul style="list-style-type: none"> • average availability of areas for buffering 	<ul style="list-style-type: none"> • waiting time at terminal • number of (un)loaded containers per hour
CT operator - rail carrier	<ul style="list-style-type: none"> • degree of flexibility (e.g., regarding additional services, for instance availability of special wagons, provision of single transport services beyond main transport relations) • average train cancellation days per year 	<ul style="list-style-type: none"> • number of locomotive engineers changes on one relation • delay of locomotive at the railroad yard
3PL - CT operator	<ul style="list-style-type: none"> • quality index for evaluation of CT operator as supplier of terminal-to-terminal services • average adherence to schedules of block trains 	<ul style="list-style-type: none"> • availability of transport capacities • transport loss ratio of terminal-terminal-services

Table 2 - 11: Selected performance indicators at the dyadical level.³²⁶

The evaluation of the entire CT concept is accomplished at the so-called '*concept level*'. Hoffmann (2006) introduced the term '*network level*', but the term is misleading, since this thesis takes in an even wider perspective. Although Hoffmann (2006) interpreted the CT concept as a SC itself, an encompassing SCM perspective is not taken. The term '*concept level*' expresses that all CT actors are encompassed: road and rail carriers, terminal operators, 3PLs, CT operators and shippers. This understanding does not equal the SC understanding of the thesis in hand. Neither the upstream processes of suppliers nor downstream processes towards the end customer are included in the evaluation on this concept level. Hoffmann gathered the performance of the CT chain under this term. She suggested that, for instance, the performance of a terminal-to-terminal service can be expressed by the degree of the fulfilment of value-added services (strategic dimension) or by the adherence to schedules of regular train departures (operative dimension). Figure 2 - 11 gives an overview of the strategic and operative performance indicators for the entire CT concept.

³²⁶ cf. Ibid., p. 173.

strategic / operative performance indicators	indicators for strategic performance	indicators for operative performance
3PL - CT operator - rail carrier - terminal operator (terminal-terminal services)	degree of fulfilment of value-adding services degree of flexibility regarding fluctuations in demand or relations for occasional transport	adherence to schedules of regular train departures reliability of provision of transport goods at the destination terminal for the ongoing haulage
shipper - 3PL (entire CT service)	entire costs of CT service service level level of total quality	adherence to schedules and delivery of the transport goods

Table 2 - 12: Selected performance indicators at the concept level.³²⁷

For the thesis in hand, an external perspective on the entire SC concept including the CT concept is taken. This exceeds the performance measurement levels introduced by Hoffmann (2007).

Figure 2 - 12 visualises the different consideration levels. It shows the difference between (1) the company-specific performance measurement, (2) the CT concept performance measurement and (3) the SCP measurement. The figure shows that the company-specific perspective means the focus on *internal* effectiveness. This means for the evaluation that the main objective is the competitiveness of the single company. The cross-company perspective of the CT concept and the SC concept focus on *external* effectiveness and efficacy. This expresses the focus on the main target of competitiveness as opposed to other CT or other SC concepts.

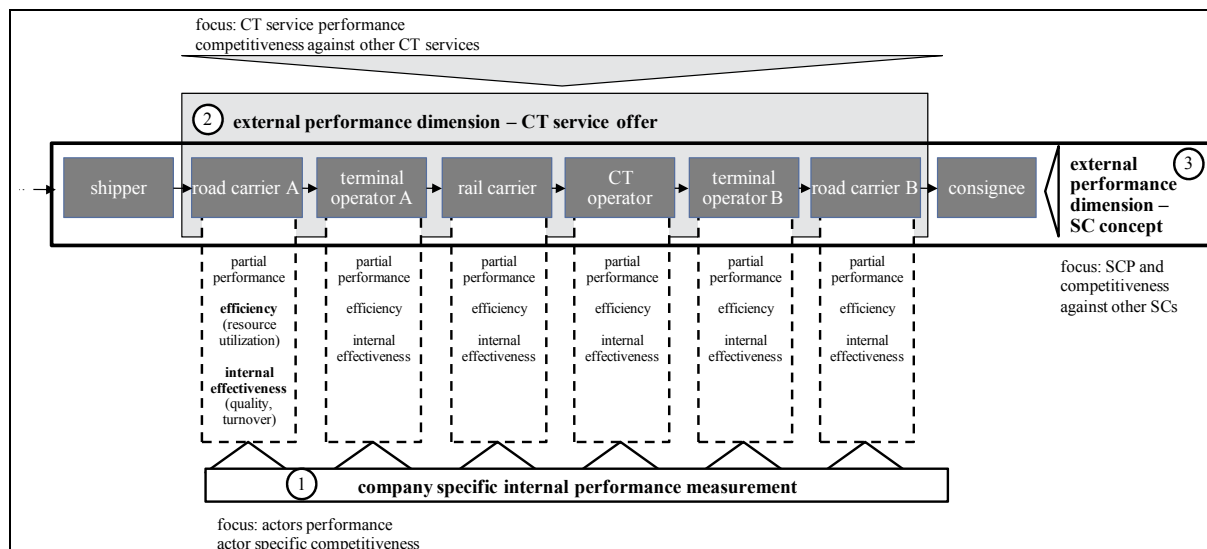


Figure 2 - 12: Performance perspective for the integration of CT into SC concepts.³²⁸

³²⁷

cf. Ibid., p. 176.

³²⁸

With significant adaptations and enhancements according to Hoffmann (2007), p. 163.

For the performance measurement on a SC concept level, specific key figures or performance indicators are required.³²⁹ These performance indicators must meet the requirements of the formal and content targets of the SCM as well as the value-oriented management (operative and strategic dimension of performance indicators) (cf. section 2.1), the requirements on performance indicators (cf. section 2.2) and the characteristics of CT (c.f. section 2.3). In the following section, a specific target system including performance indicators for CT integration into SC concepts is developed.

2.3.4 Development of a Target System for the Evaluation of CT Integration into SC Concepts

To evaluate the integration of CT into SC concepts a SC wide performance understanding is necessary. This section introduces a target system and performance indicators based on the previous considerations of the performance-oriented integration of CT into SC concepts.

Requirements on the Developed Target System

The target system must meet the requirements on performance indicators introduced in section 2.3.1. The performance indicators must be able to be integrated and aggregated. Furthermore, the indicators must be suitable to indicate and forecast prospective developments. Additionally, profitability and application orientation are central criteria.

The performance orientation implies that the developed target system includes strategic and operative aspects. Furthermore, the research focus of the thesis in hand demands a focus on technical and organisation aspects and material and information flow processes. The developed target system does not include statements on the weighting of the included performance indicators. However, recent examples show that prospectively the meaning of classical key figures, such as costs, lead times, utilisation and inventories fade into the background for performance indicators reflecting reliability, stability, flexibility and sustainability aspects. The weighting of key figures must be accomplished for company, SC and situation. Furthermore, the mutual interdependencies and

³²⁹ cf. section 2.2.

conflicts between different performance indicators are not considered.³³⁰

Performance Indicators

'Costs' and 'lead time' are 'classical' key figures expressing the efficiency of a SC concept. This means that that companies seek to reduce the value of these key figures. Lead time expresses the throughput time of an order.

However, depending on the perspective on the SC different time spans can be classified as lead time. The cost key figure encompasses all costs connected with material and information flow processes. Furthermore, flexibility is included in the target system to do justice to changing SCP requirements or short-term changes necessary because of end customer changes or interruptions in material flow processes.

The 'utilisation of capacities', and 'inventory levels' are classical key figures with a direct impact on SC costs. These key figures can be allocated to the effectiveness dimensions since material flow processes are configured to reach a defined level of these key figures. 'Adherence to schedules' is also a 'relative' key figure. It contributes to the increased meaning of SC stability and reliability.

Taking regard to the ongoing sustainability discussion, next to these material and information flows, emissions are included in the target system. In practice, there are several approaches to calculate so-called carbon footprints. These footprints aim at the inclusion of CO₂ emissions into the life cycles of single products. Furthermore, sustainability is a central aspect for companies to shift transport volumes from unimodal road to CT (cf. section 2.2.3.3). Figure 2 - 13 illustrates the SCP target system for the integration of CT into SC concepts.

<i>regard to material and information flow</i>	<i>efficiency</i>	lead time	<i>effectiveness</i>	adherence to schedules
		flexibility		utilisation of capacities
				inventory level
<i>additional key figures</i>		costs		
		emissions		

Figure 2 - 13: Target system of SCP and performance indicators for the integration of CT into SC concepts.

The developed target system serves to evaluate the integration of CT into the SC con-

³³⁰ For instance, the so-called 'scheduling dilemma' describes the conflict between capacity utilisation and adherence to schedules and lead time. cf. Nyhuis et al. (2008).

cept. However, the following section introduces configuration theory to support the problem solution process.

2.4 Configuration Theory as Theoretical Research Approach for Integrating CT into SC Concepts

This section introduces configuration theory as the theoretical research approach to support the solution process for the problem of CT integration.

The first step clarifies the meaning of theory application for practice-oriented research. In particular, the importance of the research perspective for the appropriate theory choice is highlighted. The second step introduces common theoretical research approaches for the problem of SC integration. The third step describes the selection of configuration theory and its application to the given problem formulation.

2.4.1 Meaning of Theory Application for Application-Oriented Research

The explanation of a problem formulation is supposed to be theory-guided whenever possible. Following Wolf (2005), the theoretical foundation of application-oriented research is essential.³³¹ For the thesis in hand, the theoretical foundation supports the development of propositions on the integration of CT into SC concepts.³³²

Theories provide general arguments to understand real world phenomena by abstracting singular instances that support the neutral researcher's perspective. They can be understood as distillates of the multiplicity of previous research projects. By means of theories, the historical development of new ideas and content can be tracked and are thus, interpreted as condensed information on practical challenges at certain time points by analysing emerging theoretical approaches. The theory foundation supports the researcher by integrating the research results into the existing knowledge base within the research discipline. Thus, the researcher's risk, for instance, regarding redundancy and lacking connectivity can be reduced.³³³

'Theories serve to describe, to explain and predict functions and issues. Usually, in economic research theories consist of a cross-linking of established hypotheses or approved empirical laws.' (translated according to Bortz & Döring 2005, p. 17).

³³¹ cf. Wolf (2008), pp. 54.

³³² cf. Stölzle (1999), p. 196.

³³³ cf. Wolf (2008), pp. 54.

Consistently in literature there is no theoretical approach that can entirely explain the phenomenon of SC control.³³⁴ SCM can be characterised by its cooperative character. Hence, theoretical approaches to the generation and control of cooperative relationships are commonly used to explain SCM and integration issues.³³⁵ The choice of suitable theoretical approaches is limited because of the neutral research perspective.

The following section briefly introduces common theoretical approaches towards the problem of SC integration.

2.4.2 Theoretical Solution Approaches towards SC Integration

This section introduces different approaches to theoretically explain the generation and control of cooperative relationships. As shown in section 2.1.3, cooperation serves as a basis for SC integration. Thus, the introduction of CT transport into SC concepts can be understood as the generation of a cooperative relationship between CT actors and shippers. The advantages and disadvantages of each theoretical approach are briefly discussed with regard to the transferability of argumentation patterns to the problem of CT integration into SC concepts.

To explain the cooperative inter-organisational relationships in SCM research the approaches of *transaction cost and agency theory*, as two elements of *new institutional economics theory*, are commonly applied.³³⁶ All new institutional theory approaches can be characterised by their focus on individual characters (either people or institutions) and the assumption of opportunistic behaviour. The *property rights theory* usually delivers no explanatory contribution to the questions of SC cooperation.

Transaction cost theory is an appropriate decision support framework regarding the chosen degree of vertical integration (make-or-buy) and serves to explain cooperative behaviour. It is also applied to design cooperative relationships (e.g., supplier–customer relationships) and respective logistics systems.³³⁷ To derive design-oriented statements transaction cost theory is often supported by situative approaches.³³⁸

³³⁴ cf. Gareis (2002), p. 175; Schmitz et al. (2004), p. 712; Staber (2000), pp. 58; Stölzle (1999), p. 25; Wohlgemuth (2002), p. 48.

³³⁵ cf. Karrer (2006), p. 69; Stölzle (1999), p. 25.

³³⁶ cf. Erdmann (2003), pp. 33; Gareis (2002), p. 186; Heusler (2004), pp. 111.; Rothfuss (2005), pp. 42.; Wolf (2008), pp. 327.

³³⁷ cf. Höll (2008).

³³⁸ See for instance Aggarwal (2007); Meisner Rosen et al. (2000); Skjoett-Larsen (2000); Stölzle (1999), p. 26.

Agency theory focuses on the contractual design and behaviour control within dyadic relations in which one party constitutes the agent hired by a principal.³³⁹ The relevant environmental factor is the incomplete and asymmetric information. The approach is characterised by a hierarchical relational structure.³⁴⁰

Systems theory is commonly applied to support the understanding of cooperative relationships. It has been enhanced to new systems theory. Here, systems are made up of related and interdependent components, including boundaries, outputs, inputs, transformation mechanisms (ways of converting inputs to outputs) and interfaces interacting with their environments. A system can be characterised by complexity and autonomy and cannot be directly influenced by the environment. Only the scope for autonomous control can be generated from outside the system.³⁴¹

Decision theory is commonly applied to explain logistical problems. Application fields include the definition of decision time points, the structuring of a problem or the development of a decision process.³⁴² In this context, *game theory* is applied to understand and predict the behaviour of players in a cooperative relationship.

Stölzle (1999) suggested applying these approaches to *organisational procurement behaviour* for the analysis of interactions between different actors, especially for buyer–supplier relationships.³⁴³ The approaches distinguish between different types of interactions (dyadic-personnel, multi-personnel, dyadic-organisational, multi-organisational).³⁴⁴

If there is a strong power and dependence relationship between cooperating actors, the *resource dependence approach (RDA)* can offer an explanation. The restricted availability of resources forces companies to buy these. This creates a situation of dependency. The RDA is a behavioural approach that provides explanation patterns towards dependency analysis between SC players and their behaviour.³⁴⁵

The structure of relationships between organisations in SCs can be compared with a network. In contrast to systems theory, *network research and interaction approaches* not only focus on the elements and connections within a system, but also consider the

³³⁹ cf. Eisenhardt (1988), p. 489; Eisenhardt (1989), p. 60; Lassar et al. (1996), p. 613.

³⁴⁰ See Hochhold et al. (2009), pp. 131.

³⁴¹ See for instance Forrester (1995); Lane (2000); Luhmann (1999); Schwaninger et al. (2008), p. 286; Weisbuch (2000).

³⁴² cf. Lassar et al. (1996); Richardson (1991); Sterman (2001); Stevenson et al. (2000), p. 27; Weisbuch (2000).

³⁴³ cf. Ekwall (2007), pp. 27.; Stölzle (1999), p. 27.

³⁴⁴ cf. Kirsch (1973), pp. 112.

³⁴⁵ cf. Brunner (2008), pp. 31; Stölzle (1999), pp. 28.

interactions between these. As a result, network theory is especially appropriate for behavioural problems.³⁴⁶ There are two main streams of network research aiming at (1) the generation of networks and (2) the management of networks. There are several overlaps between network approaches and other theories. Thus, network research has not yet the status of its own theory. Nevertheless, it is often applied together with systems theory to logistics problems.

Situative approaches are organisational theories. They are also called *contingency approaches*. They allow statements about the choice of different design alternatives for a given problem formulation with regard to a specific target system. Considering the specific framework conditions concrete problem solution approaches can be derived from these approaches.³⁴⁷

This brief overview of available theoretical solution approaches in the field of SC cooperation serves as the basis for the selection process described in the following section.

2.4.3 Selection of Theoretical Approaches with regard to the Research Problem and Perspective

This section describes the selection of configuration theory to provide a theoretical explanation to the given research problem. To select suitable theoretical approaches, the research perspective is the guiding criterion.

This thesis takes a neutral and rational research perspective. The focus is on the integration of material and information flow processes in SCs including CT concepts. Following the terminology of Cooper (1997), the thesis focuses on SC integration in terms of *SC process integration*³⁴⁸, rather than *SC structure integration*³⁴⁹ and *SCM integration*.³⁵⁰ Thus, the focus is on the technical, physical and organisational aspects of the integration problem, rather than managerial and behavioural approaches.³⁵¹ This focus

³⁴⁶ cf. Grant (1991), p. 29.

³⁴⁷ See for example Carter et al. (2008), Kannan et al. (2005), p. 30.

³⁴⁸ SC process integration means the cross-company integration of business processes. These efforts can span all value-adding levels, for example research and development, demand planning, disposition or capacity utilisation processes.

³⁴⁹ (SC relationships, inter-organisational business units) SC structure integration deals with the development of SC relationships (e.g., trust building activities) and the introduction of cross-company organisational units (e.g., project teams).

³⁵⁰ c.f. section 2.2.1 Cooper et al. (1997), p. 70. SCM integration means benefits for all involved SC members. Companies can access rare resources and new markets. They can share risks and reach synergy effects, e.g., developing new products and services, economies of scale and gain knowledge.

³⁵¹ cf. section 2.1.6.

reduces the problem's complexity, because all actor-specific aspects of the management of SCs are excluded from consideration.

Several theoretical approaches either consider actor- and organisation-specific problems or provide an explanation for the linking of objects in a network (e.g., network theory). For the research problem of CT integration into SC concepts a theoretical approach is required that is actor-neutral and focuses on the identification of successful configurations of the CT and SC concepts as well as integrative measures to improve SCP.

Since the research focuses on technical and organisational management components, all theoretical approaches towards the behaviour of individuals or organisations are excluded, such as the approaches of *new institutional theory*, *decision theory*, *game theory* or *RDA*,³⁵² from further consideration.

Furthermore, all approaches for the explanation of relationships between people or organisations are excluded, such as *network research*, *organisational procurement behaviour and interaction approaches*. To ensure a strong focus on the core problem of CT integration, the willingness of actors to cooperate and to contribute to the performance-oriented design of these cooperations is assumed.³⁵³ Systems theory also focuses on the explanation of cooperative relationships. Furthermore, it assumes that the environment can only indirectly influence the system.

The application of situative approaches allows consideration from an objective perspective. *Configuration theory* is a development of situative theory. It aims at the consideration of different internal and external context factors explaining the development of different organisational structures. In particular, configuration theory supports the research process by linking the results of different research fields in a consistent overall picture.³⁵⁴ The configuration approach aims at the identification of inherent consistent patterns of design and context variables, so-called '*configurations*'.³⁵⁵ Transferred to the given research problem, this means that that consistent configurations as combinations of SC concept types and CT concept types are defined. These configurations are the basis for the identification of situative successful solutions for the integration problem.³⁵⁶

³⁵² Further behavioural approaches are e.g., stimulus-contribution theory, hierarchy of needs and coalition theory.

³⁵³ This also explains the only brief introduction to the motivation for CT integration.

³⁵⁴ Wolf (2008), pp. 452.

³⁵⁵ Ibid., p. 455.

³⁵⁶ cf. Klaas (2002), p. 52.

The following section briefly introduces the main characteristics of configuration theory.

2.4.4 Configuration Theory as an Explanation Approach for the Performance-oriented CT Integration into SC Concepts³⁵⁷

This section discusses configuration theory as an explanation approach for the research problem of the performance-oriented CT integration into SC concepts. Configuration theory supports the identification of successful combinations of different CT and SC concepts, of environmental conditions as well as integrative measures.

Configuration theory is an advancement of situative theory. To understand how configuration theory supports the problem solving process, in a first step the basics of situative theory are briefly introduced.

2.4.4.1 Basics of Situative Theory

The research objective of situative theory is the relationship between a situation and a configuration as well as between a configuration and the success of an organisation. An organisation can be characterised by its unique, measureable, formal organisational structural characteristics. These characteristics are determined by the given context. The central assumption of situative theory is that if organisational structure³⁵⁸ is aligned to the specific context, the organisation is '*efficient*'³⁵⁹. Thus, situative theory denies the existence of universal efficient organisational structures. It rather searches for formal structures that lead to a situatively reasoned efficiency through a '*fit*' with specific context factors.³⁶⁰

The results of this analysis are applicable in all companies not only in the given context. However, there is no universality of characteristics of behaviour and configurations, but rather a universality of relationships between these.³⁶¹

³⁵⁷ Also called 'second order contingency theory' or the 'gestalt approach'.

³⁵⁸ The behaviour of the member depends on the organisational structure as well as other external factors. According to Kieser, the behaviour can be excluded since the impact of behaviour is empirically difficult to measure. Thus, a structure-conform behaviour is assumed. Kieser (1999), p. 176; Kieser et al. (1992), p. 206.

³⁵⁹ There is no differentiation between the economic basic terms of '*effectiveness*' and '*efficiency*'. In this context, efficiency means meeting of organisational targets or, in general, the surviving of an organisation. cf. Kieser et al. (1992), p. 57; Kieser (1999), pp. 175; Staehle (1976), p. 36.

³⁶⁰ cf. Scherer et al. (1998), p. 334; Staehle (1976), p. 38; .

³⁶¹ This is an important difference in comparison with systems theory (makes statements only for specific situations).

The central research question of situative theory is:

'Which context factors explain (the presence of) different configurations?' (own translation according to Wolf (2008), p. 200)

To answer this main question a second question must be answered:

'How can the situation and configurations of the organisation be operationalised?' (own translation according to Wolf (2008), p. 200)

Several publications have dealt with the questions of (1) to what extent different configurations affect the success of organisations and (2) to what extent different situation/configuration constellations differ from each other regarding their success. The term of success is operationalised in several different forms. Often, the target systems of organisations are applied as reference points for success measurement.³⁶²

Transferred to the problem of CT integration into SC concepts, these basic considerations of situative theory can be interpreted as follows. The term '*situation*' encompasses the relevant environmental factors of an organisation as well as the organisation's characteristics. These organisational characteristics correspond to the term '*SC concept*'. The environmental characteristics include '*SC strategy*' and '*SC environment*'. A '*configuration*' means the combination of a specific '*SC concept*' and a specific '*CT concept*'. The connection of situation and configuration determines the success of the specific configuration.

To apply situative theory, the considered variables must first be determined. There are '*context variables*', '*design variables*' and '*success variables*'. In a second step, the variables have to be specified and the relationships between the variables have to be defined.

The advantages and disadvantages of situative theory have been widely discussed.³⁶³ One development to overcome the disadvantages is configuration theory.

2.4.4.2 Configuration Theory as an Advancement of Situative Theory

Configuration theory sets up the disadvantages of situative theory.³⁶⁴ Configuration theory aims to analyse multiple variables and their characteristics to determine the spe-

³⁶² cf. Wolf (2008), p. 200.

³⁶³ See Ibid., pp. 215.

³⁶⁴ Several authors have focused their research on the deficiencies of this approach. cf. Sennheiser et al. (2008), p. 452. The main critical points of mono causality, uncreative retesting, un-differentiation, linear relationships, ignorance of equifinality, context determinism and missing longitudinal section led to several enhancements of the theory aiming at an integrated design-oriented

cific organisational situation. The target of configuration theory application is the analysis of typical variable configurations and the identification of successful variable configurations. These configurations can be derived either empirically or from the literature.³⁶⁵

In contrast to situative theory, configuration theory assumes a multidimensionality of cause-and-effect patterns.³⁶⁶ Furthermore, configuration theory suggests the existence of non-linear interdependencies between context and design variables.³⁶⁷ For the performance-oriented integration of CT into SC concepts, this means that there can be more than one successful configuration of design variable for a given configuration of context variables. Furthermore, there can diverse integrative measures suitable for the specific configuration.

The basic assumption of situative theory is that an organisation is successful if the context and design variables are congruent.³⁶⁸ According to the '*consistency efficiency hypothesis*' the

'[...] effective structuring requires a close fit between the contingency factors and the design parameters'. (Mintzberg (1979), p. 219)

Configuration theory enhances this understanding by using the so-called '*configuration hypothesis*'.³⁶⁹

'[...] effective structuring requires an internal consistency among the design parameters' (Mintzberg (1979), p. 219)

The '*enhanced configuration hypothesis*' summarises both hypotheses. This assumes that consistent combinations of design variables must correspond to consistent combinations of internal and external context factors.³⁷⁰

'[...] the characteristics of organizations fall into natural clusters, or configurations. When these characteristics are mismatched - when the wrong ones are put together - the organizations does not function effectively, does not achieve full harmony.' (Mintzberg (1981), p. 103)

analysis of phenomena. cf. Höll (2008), Wolf (2008); Miller et al. (1984); Macharzina et al. (1991). All these publications aim at the identification of complex context-design-success patterns.

³⁶⁵ cf. Macharzina et al. (2005); Wolf (2008), p. 457.

³⁶⁶ cf. Wolf (2000), pp. 4; Miller (1981), pp. 3; Mintzberg (1983), pp. 60.

³⁶⁷ cf. Wolf (2008), p. 452.

³⁶⁸ cf. Mintzberg (1979), p. 219; Staehle (1994), p. 59,

³⁶⁹ cf. Klaas (2002), p. 104; Mintzberg (1979), p. 219.

³⁷⁰ '[...] effective structuring requires a consistency among the design parameters and contingency factors.' Mintzberg (1979), p. 220, cf. also Scherer et al. (1998), p. 336, Staehle (1994), p. 59, Wolf (2000), p. 25.

Thus, configuration theory assumes the existence of consistent organisational configurations that can be characterised by harmonic patterns between design variables and context variables.

Basic Principles of Configuration Theory

Configuration theory is based on four general principles: (1) fit concept, (2) equifinality thinking, (3) configurational thrift and (4) discontinuity of transition.³⁷¹

(1) The *'fit concept'* postulates that the success of an organisation can be interpreted as the consequence of the fit of at least two variables.³⁷² This general concept is applied to the development of the conceptual research framework of the thesis in hand. It is assumed that the fit of the CT and SC concepts as well as the fit with specific integrative measures and instruments can lead to or improve SCP. These two 'fits' correspond to the idea of internal and external coherence.

The fit of the CT and SC concepts (internal coherence) and the fit of these with the environment (external coherence) are necessary to achieve SCP.³⁷³

(2) *'Equifinality'* means that the same end state can be reached starting from different initial situations (functional equivalence of situations). Transferred to the problem of CT integration, this means that there are different ways to improve SCP from any SC concept initial situation. Wolf (2000) identified the potential of information processing to be central. This encourages focusing on the informational and technical aspects.

(3) *'Configurational thrift'* means that in reality there are a limited number of successful configurations. This number of configurations is many times smaller than is the number of variable combinations resulting from a systematic combination of all characteristics.³⁷⁴ Thus, it can be assumed that groups of the CT and SC concepts can be identified that fit together with more or less effect on SCP. However, this element of configuration theory implies that despite the choice of situative approach general guidance can be derived in the thesis in hand.

Groups of the CT and SC concepts can be assumed to work together with more or less performance effect. However, this element of configuration theory implies that, al-

³⁷¹ cf. Wolf (2000), p. 465; Wolf (2008), pp. 454.

³⁷² cf. Wolf (2008), p. 465.

³⁷³ cf. Ibid., p. 465.

³⁷⁴ In total, there are seven reasons for this assumption. cf. Henselek (1996), p. 274.

though we choose a situative approach, we can derive general guidance from our research. In total, there are seven reasons for this assumption.³⁷⁵

(4) *Discontinuity of transition*: Regarding the development of configurations, the theory implies that transitions are not steady, but soaring. According to Wolf (2000), there is an alternating sequence of momentum periods and transition periods.³⁷⁶ Thus, configuration theory encourages longitudinal analysis. According to the integration of CT, specific adjustments have to be considered over time. The success of integration has to be evaluated over time since the effects of changes are time lagged.³⁷⁷

The following section addresses the application of configuration theory to the given research problem after this rather general outline.

2.4.4.3 Application of Configuration Theory to the Problem of the Performance-Oriented Integration of CT into SC Concepts

Configuration theory supports the development of a situative workable orientation framework for the integration of CT into SC concepts. This framework consists of a restricted number of configurations, which reflect the major part of real SC concepts including CT. This set of configurations can serve as a diagnostic instrument³⁷⁸ as well as a heuristic orientation framework for solving design problems in practice (*'design function'*). Furthermore, these SC concept configurations (including CT) can serve as a framework for the systematic exploration of integration problems in the field of transport and SCM (*'knowledge function'*). Thus, the set of SC concept configurations can be understood as conceptual guiding points for the theory-guided exploration as well as for the application-oriented design of SC design and CT.

Configuration theory can explain the success of specific CT concepts, specific SC concepts and specific integrative measures and instruments. More precisely, configuration theory supports:

- (1) The identification of typical context variables configurations, namely different CT concepts that appear in practice and that have a comparable character in terms of CT integration.

³⁷⁵ cf. Ibid., p. 274.

³⁷⁶ For justification of these assumptions cf. for example Veliyath et al. (1995); Wolf (2008), pp. 23.

³⁷⁷ cf. Wolf (2008), pp. 23

³⁷⁸ cf. Klaas (2009).

-
- (2) The identification of typical and successful combinations of context variables, namely CT concepts and SC concepts. The identified successful combinations are called 'gestalts'.
 - (3) The identification of typical and successful combinations of integrative measures and instruments for the identified configurations and gestalts.

In this context, success means the adherence to the developed target system of SCP (cf. section 2.3.3.2). In practice, SCP improved with a unimodal road transport serves as the benchmark for the evaluation of the CT integration.³⁷⁹

Thus, configuration theory supports the answering of the second and third research questions.

The following section summarises and joins the main findings on configuration theory with the central findings of chapter 2.

2.5 Intermediate Findings

This section joins the main findings of the second chapter of the thesis in hand. The second chapter concretises the research problem and introduces the state of the art as the basis for the application of a theoretical solution approach. Thus, chapter 2 lays the foundation for answering the research questions presented in chapter 1.

Concretisation of the Research Problem

The second chapter concretises the problem of performance-oriented CT integration . The chapter identifies associated challenges caused by CT integration into SC concepts in three steps. First, the challenge of SC integration in general, second the challenges caused by the complexity of CT and third the challenge of a SC-wide performance orientation are illuminated. Furthermore, the second chapter introduces configuration theory to support the problem solution process. The section highlights that the integration of material and information flow processes in SCs is generally challenging. The complexity of CT and the increasing performance orientation of SC actors further exacerbate this integration. Configuration theory allows the consideration of this quantity of different aspects. It also enables the development of a conceptual research framework, in which the SC concept is the design variable, the CT concept acts as the framework vari-

³⁷⁹ cf. section 2.2.2.

able and both are connected by a 'fit', namely the integration of material and information flow processes, leading to improved SCP.

Five categories of integrative measures and instruments for SC integration were identified in a comprehensive literature review. These findings are the basis for the analysis presented in chapter 4. Here, the instruments and measures are discussed regarding their suitability in the field of CT and regarding their impact on certain SCP requirements.

Additional Time Amounts and Coordination Effort in Comparison with Unimodal Road Transport

The second chapter points out the competitive situation of CT and unimodal road transport. Additional transshipment, handling and overheads increase time requirements and the multiplicity of CT actors raises the necessary coordination effort. Both aspects result in an increased cost level in comparison with unimodal road transport. Shippers and policymakers increasingly perceive CT as a promising solution to overcome problems in unimodal road transport, such as rising transport costs, congestion, sustainability initiatives and transport political regulations. However, many shippers claim that CT does not meet SCP requirements. Table 2 - 13 summarises the main contradictions and contrasts shippers' performance requirements with CT characteristics.

Shippers' performance requirements	CT characteristics
<ul style="list-style-type: none"> • Shippers aim to reduce lead times and imply short transport times and high adherence to schedules. 	<ul style="list-style-type: none"> • CT requires additional time quotas in comparison with unimodal road transport.
<ul style="list-style-type: none"> • Shippers aim to reduce costs and to reach a high level of flexibility. 	<ul style="list-style-type: none"> • CT requires special investments in specific load carriers and handling equipment. Therefore, CT actors require long planning horizons to redeem investments.
<ul style="list-style-type: none"> • Shippers aim to introduce lean structures and to avoid unnecessary processes or the waste of resources. 	<ul style="list-style-type: none"> • CT requires additional processes (transshipment, rail transport, buffering for bundling purpose etc.).
<ul style="list-style-type: none"> • Shippers demand constant accompaniment of transport goods. 	<ul style="list-style-type: none"> • In a CT concept on rail transport the goods are unaccompanied.
<ul style="list-style-type: none"> • Shippers do usually not include transport actors in their planning activities and deny access to information platforms and forecasts. 	<ul style="list-style-type: none"> • The multiplicity of actors and partial processes increase coordination efforts and exacerbate capacity planning.

Table 2 - 13: Comparison of shippers' performance requirements and CT characteristics.

As the chapter points out, stable, predictable transport volumes with comparably long lead times and regular frequencies are particularly suitable for CT. These characteristics allow for the realisation of bundling effects and the reduction of planning efforts and overheads. Furthermore, CT networks are suitable for the transport of packaged goods with comparably long lead times.

Changing Framework Conditions Require an Innovative Target System

SCP is introduced as a target system that is suitable to meet the changing framework conditions of recent SCs. The section points out that a classical target system must be

aligned with regard to financial- and value-oriented purposes. This target system reflects operational and strategic aspects and includes the performance indicators of the efficiency and effectiveness dimensions. This means that that in the context of CT, new performance indicators must be applied to the evaluation of SCP. The reasons for this include the increasing vulnerability of SCs, demanding SCP requirements and uncertainty over energy prices. Thus, especially, the aspect of sustainability must be included and a re-weighting of performance indicators in favour of adherence to schedules and flexibility is necessary.

The second chapter concretises the research problem and introduces the first aspects for the development of solution approaches to answer the research questions presented in chapter 1. Henceforth, chapter 3 introduces a structured classification approach to describe SCP requirements regarding the embedded and linking transport concepts. On this basis, the meaning of CT as an element of SC concepts is discussed. The differentiation into procurement, production, procurement and transport concepts serves as the basis for developing the conceptual research framework in chapter 4.

3 CT as an Element of SC Concepts

The third chapter addresses the meaning of CT as an element of SC concepts. It clarifies the position and the meaning of the CT concept for SCP. Therefore, the relationship between the procurement, production and distribution concepts and the embedded and linking transport concept is worked out. In particular, the relevant cause-and-effect relationships between the elements of the sub-concepts and the elements of the CT concept are identified.

Initially, the third chapter analyses the construct of SC concepts as the operationalisation and implementation of a specific SC strategy (section 3.1). The SC concept interprets and transfers the SC strategy to the defined material and information flow processes and builds up corresponding organisational structures as well as management processes. For the precise description of the SCP requirements regarding transport concepts, a structured description framework with seven performance dimensions is developed (section 3.2). Based on this classification the SC sub-concepts, namely procurement, production and distribution concepts, are analysed regarding their requirements on the embedded and linking transport concepts (section 3.3). In particular, the meaning of the SC concept configuration on the integration of CT concepts is worked out (section 3.3). Finally, a typology for CT concepts and corresponding performance profiles is developed (section 3.4). The intermediate findings are summarised in section 3.5.

3.1 SC Concepts as the Operationalisation of SC Strategies

SC strategy has a long-term character. The SC strategy itself does not provide information about the concrete design of the material and information flow level and the corresponding structures and management processes. In the thesis in hand, a SC concept is understood as this missing operationalisation of SC strategy.¹

¹ On the basis of Heuermann (2002); Hilletoft (2009); Shewchuck (1998).

3.1.1 SC Strategies as the Basis for SC Concept Configuration

Actions and parameters are of strategic character if they lead to the creation and exploitation of success potential or if they influence the long-term development of a company.² A strategy ensures that short-term decisions correspond with the company's long-term objectives.³ Thus, strategic management research differentiates between levels of strategy. According to Hofmann (2010), four generic levels of firm strategies can be distinguished.⁴

(1) The '*SC strategy*' deals with the strategic alignment of inter-organisational activities.⁵ Both structural and dynamic components are necessary for this. Structural activities determine relationships, network structure and focus on the alignment of target systems within a network, whereas dynamic components work on the combination of resources together with other companies in inter-organisational routines or projects.⁶

(2) The '*corporate strategy*' aims at the definition of target industries and the composition of business activities.⁷

(3) A '*business unit strategy*' focuses on the realisation of competitive advantages and the question of how a company should compete in the chosen market.⁸ This means that companies aim at the production of goods or services at a lower cost level than competitors do or to differentiate from the competitors by unique value-adding activities.⁹

(4) '*Functional strategies*' refer to either operational or supporting activities. Operational activities include sourcing, production, distribution and logistics activities. Supporting activities include human resources or IT. The functional strategy must be aligned with the other components of firms' strategies.

Companies increasingly realise the need to integrate information and material flow processes with upstream and downstream business partners.¹⁰ Westbrook and Frohlich (2001) described this as a change from a vertical alignment of activities to a horizon-

² cf. Sennheiser et al. (2008).

³ cf. Grant (2002), p. 793.

⁴ cf. Brown et al. (2005), pp. 256.

⁵ Hofmann uses the term 'network strategy'. cf. Hofmann (2010) pp. 256.

⁶ cf. Ibid., pp. 256.

⁷ cf. Ibid.; Bowman et al. (2001); Grant (2002).

⁸ cf. Hofmann (2010); Grant (2002).

⁹ cf. Hambrick (1980); Porter (2004).

¹⁰ cf. Thompson et al. (2005); Tan (2001); van Hoek (2001).

tal alignment of activities.¹¹ The chosen SC strategy is central to the way of treatment of business partners.¹² Since SC actors aim for a common objective, companies tend to build up competitive advantages by commonly focusing on this.¹³ By this the SC differs from others by establishing a common value-adding capacity.¹⁴ The introduction of the SC strategy proves this understanding. According to Campbell and Wilson (1996), the SC strategy can be understood as an enhancement of the operations strategy.¹⁵ While the operations strategy aims to ensure that competitive priorities are accomplished by one company, the SC strategy means the objectives of the focal company deal with the SC members. Several authors have stated that to choose a suitable SC strategy the SC environment has to be carefully analysed.¹⁶

Lo and Power (2010) interpreted the SC strategy as a set of choices made by companies to match the environmental contingencies. Several authors have followed this SC strategy understanding and defined the choice of an appropriate strategy as a positioning within an environment of fundamental trade-offs.¹⁷ However, recently the understanding has changed since several companies build capabilities in groups of interest.¹⁸

The SC strategy determines the alignment of an entire SC. According to Chopra and Meindl (2004), the term 'SC strategy' can be defined as follows:

'A supply chain strategy determines the nature of procurement of raw materials, transportation of materials to and from the company, manufacture of the product or operation to provide the service, and distribution of the product to the customer, along with any follow-up service. From a value chain perspective, SC strategy specifies what operations, distribution, and service will try to do particularly well.' (Chopra & Meindl (2004), p. 29)

The definition gives an overview of the contents of the SC strategy. The definition highlights the meaning of procurement, distribution, production as well as transport and logistics processes. However, for implementation purposes the definition of a SC strategy is not sufficient. For the implementation of material and information flow processes and the corresponding organisational and management structures more spe-

¹¹ cf. Webster (2002); Lo et al. (2010).

¹² cf. Fröhlich et al. (2001).

¹³ cf. Lo et al. (2010).

¹⁴ cf. Campbell et al. (1996).

¹⁵ cf. Lo et al. (2010); Campbell et al. (1996); Lo et al. (2010); Harland (1996); Harland et al. (1999).

¹⁶ cf. Harland et al. (2001); Harland et al. (2004); Lambert et al. (1998); Lo et al. (2010).

¹⁷ cf. Ojasalo (2004); Hayes et al. (1978); Hayes et al. (1979).

¹⁸ cf. Lo et al. (2010); Ferdows et al. (1990); Lo et al. (2010).

cific determinations are needed. In the thesis in hand, this more ‘operative’ and situation-specific concretisation is named the ‘*SC concept*’.

In particular, the corporate strategy influences the SC strategy.¹⁹ If the corporate strategy is focused on service aspects, the SC strategy must ensure that products and services are available at anytime and anywhere, namely they must have an outstanding delivery service without out-of-stock situations. Therefore, the SC strategy focuses on delivery speed and accuracy. If the corporate strategy is focused on quality aspects, the SC strategy must guarantee a high level of delivery reliability with a low error rate in SC processes, including reliable quality control processes (especially regarding product quality). If the corporate strategy focuses on flexibility, the SC strategy must ensure the fast and safe product launch and the possibility of meeting fast changing customer demands. This means the SC strategy supports the production of a high product variety and reacts to fluctuations in the demand of different product types. If the corporate strategy focuses on cost aspects, the SC strategy must focus on an efficient infrastructure to reduce overall SC costs.²⁰

In the thesis in hand, the SC concept is understood as the operationalisation of the SC strategy.²¹ The SC concept considers the necessary company, product and environmental contingency factors that influence the specific design and configuration of the material and information flow processes and the corresponding structures and management processes. The SC concept determines precisely the operationalisation using resources and processes and considers the specific internal and external contingencies (framework conditions) and capacities, such as resources (e.g., personnel, technical facilities and equipment and knowhow), product characteristics, regional SC structure and performance requirements of the end customer with regard to the SC strategy.²²

Owing to this close term understanding and the tight connection between SC strategy and the SC concept, the following section introduces the basics of SC strategy development.

¹⁹ cf. for instance Rosenzweig et al. (2004); Hofmann (2010), pp. 19.

²⁰ cf. Heuermann (2002); Hofmann (2010), pp. 19; Heuermann (2002).

²¹ On the basis of Heuermann (2002); Hilletofth (2009); Shewchuck (1998).

²² cf. section 1.3.

3.1.2 Classification Approaches for SC Strategies

This section highlights the meaning of choosing the right SC strategy according to the specific demand and supply characteristics.²³ The section improves the understanding of different SC strategies and the resulting SC concepts.

As stated in the previous section, the SC strategy determines procurement, transport, service, manufacturing and distribution configurations to supply the end customer with the desired product. Shewchuck (1998) showed why different SC strategies are required for different types of products. He proved that products differ in their demand types and usually in their marketing and manufacturing environments, too.²⁴ The author distinguished between products with a '*compressed life cycle*', '*compressed time-to-market*', '*mass customisation via assembly*' and '*mass customisation via processing*'. Each product group has different marketing and manufacturing characteristics.²⁵

Fisher's Approach to SC Strategy Classification

Fisher (1997) suggested the assignment of suitable SC types according to different product types.²⁶ He stated that a mismatch of product type and SC strategy results in severe problems in business operations. The approach of Fisher has been the basis for several other SC strategy classification approaches.

Fisher (1997) assumed that functional products should be supplied by efficient (in terms of costs and productivity) 'lean' SCs. Functional products satisfy the basic needs of customers.²⁷ These usually do not change over time and are thus, stable and predictable in demand. This leads to comparably long life cycles and high competition, resulting in low profit margins. Innovative products should be supplied by responsive 'agile' SCs.²⁸ Companies aim at innovations to overcome low margins. Fashion and personal computers are obvious examples of innovative products. Fisher introduced examples of companies that aim to bring innovation to functional prod-

²³ cf. Porter (1980), p. 465.

²⁴ cf. Christopher et al. (2008).

²⁵ *Mass customisation* accomplished by processing, for instance for spectacle lenses, made-to-order shoes or clothes can be characterised by a high product variety and a single unit demand with very short lead times. The production environment enables the high product variety by on-the-spot processing and a shallow bill of material. The different product types impact the other SC activities. To get further information on the choice of a suitable SC strategy the information and the material flow de-coupling points have to be identified. cf. Shewchuck (1998), p. 461; Christopher et al. (2008); Mason-Jones et al. (1997).

²⁶ cf. Naylor et al. (1999).

²⁷ cf. Fisher (1997).

²⁸ cf. Ibid.; Fearne et al. (2006).

ucts, such as Starbucks²⁹ and Ben & Jerry's³⁰ with new flavours and innovative shop concepts.³¹

Lean SCs emphasize efficiency and bring along the risk of mismatch between production and customer demand. Agile SCs focus on responsiveness and may cause a risk of a low level of production efficiency.³²

Following Fisher (1997), an efficient SC aims to '*[...] supply predictable demand efficiently at the lowest possible cost*' (Fisher (1997), p. 108), whereas a responsive SC focuses on the fast reaction on customers' needs and thus, aims '*[...] to minimize stockouts, forced markdowns, and obsolete inventory*'. (Fisher, 1997, p. 108) According to Fisher's understanding, a SC strategy includes several corporate operational strategies. These include a manufacturing focus, inventory strategy, corporate meaning of lead times and product design strategy. Furthermore, supplier selection criteria are included.

Works Extending Fisher's Model - Development of Christopher's Generic SC Strategies

Several authors have since extended Fisher's model. However, others disagree with the approach of product nature as the only or main factor for SC strategy choice.

Naylor et al. (1999) combined Fisher's model with the manufacturing paradigms of lean and agile.³³ Setting cost and quality, lead time and service level as well as the stability of demand as classification elements, they distinguished between lean, agile and leagile SC strategies.³⁴ Leagility combines both leanness and agility objectives. Processes upstream of the customer decoupling point apply lean processes. Processes downstream of the customer decoupling point apply agile processes. A leagile system tends to find equilibrium between cost reduction and fast customer response.

Further researchers have reworked the categorisation of products and introduced differentiated categories (for instance, the 'innovative-unique' type³⁵ and 'hybrid' type). Among others, product complexity was suggested to be a significant aspect of SC

²⁹ International retailer specialised in coffee products. Starbucks buys, roasts and sells coffee products in the owned and licensed shops. For further details see www.starbucks.com.

³⁰ US ice cream producer owned by Unilever. For further details see www.benjerry.com.

³¹ cf. Hilletoft (2009), p. 106.

³² cf. Fisher (1997), p. 107.

³³ cf. Ibid.

³⁴ Similar classification approaches were proposed by Naylor et al. (1999); Childerhouse et al. (2000); Christopher et al. (2001); Mason-Jones et al. (2000).

³⁵ cf. Startton et al. (2003).

strategy choice.³⁶

Some authors have supported Fisher's model, but claimed that product nature is not only influenced by demand aspects,³⁷ but that product architecture, life stages, customisation level and number of parts are also relevant characteristics. Vitasek et al. (2003), for instance, proposed the consideration of volume demand and variability.³⁸ Cigolini et al. (2003) developed a conceptual framework for the choice of a SC strategy according to product life cycle and production complexity.³⁹

Pagh and Cooper (1998) proposed product life cycle, product customisation, product variety, product value, relative delivery time, delivery frequency and uncertainty of demand as relevant classification variables.⁴⁰ The four types of SC strategies, namely full speculation, logistics postponement, manufacturing postponement and full postponement, go back to the authors. Lamming et al. (2000) set product innovation, product uniqueness and product complexity as classification variables to distinguish three different strategies.⁴¹

Another group of researchers have argued that sources of uncertainty (not only demand uncertainty) should be considered in the SC strategy since it deals with downstream and upstream partners. Sources for uncertainty include raw materials procurement,⁴² production uncertainties (caused by lead time variations)⁴³ and the capacity restrictions of focal companies and suppliers, which were not considered in Fisher's model.⁴⁴

Based on these considerations, Christopher et al. (2005) introduced a classification of SC strategies according to three parameters: (1) product type (standard vs. special), (2) demand type (stable vs. volatile) and (3) replenishment lead times (short vs. long).⁴⁵ Special products with low volume and irregular demand can be characterised by short life cycles and a high level of individualisation. A standardised product with stable demand and high volumes can be characterised by longer life cycles and only limited possibilities for customisation. Replenishment lead time is identified as the

³⁶ cf. Lamming et al. (2000); Christopher et al. (2002), Lamming et al. (2000); Lo et al. (2010).

³⁷ cf. Ramdas (2003); Catalan et al. (2003); Lo et al. (2010); Ramdas (2003).

³⁸ cf. Wong et al. (2005).

³⁹ cf. Vitasek et al. (2003).

⁴⁰ cf. Cigolini et al. (2004).

⁴¹ cf. Pagh et al. (1998).

⁴² cf. Lamming et al. (2000); Ho et al. (2005); Lee (2002).

⁴³ cf. Lo et al. (2010).

⁴⁴ cf. Ho et al. (2005).

⁴⁵ cf. Kim et al. (2002); Christopher (2005a), p. 283; Christopher et al. (2006), p. 463.

central parameter for the choice of a suitable SC strategy because it significantly influences the responsiveness of the SC. Product type and predictability are related, so that the derived taxonomy includes only two dimensions.

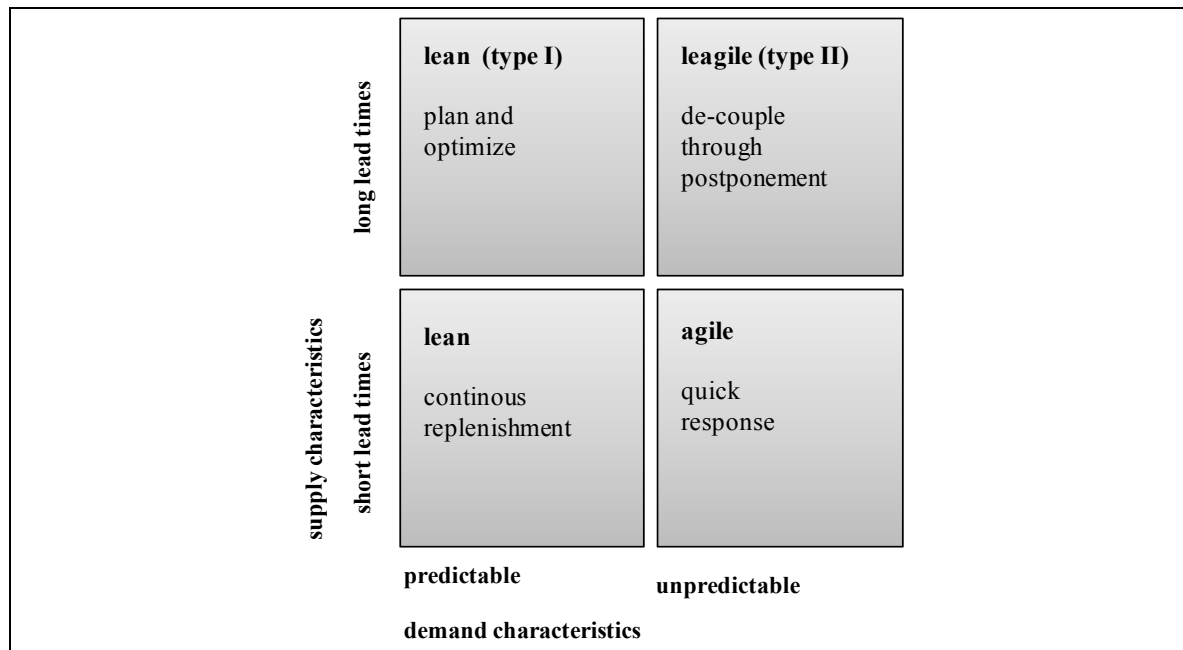


Figure 3 - 1: Generic SC strategies.⁴⁶

If demand is stable, and thus, predictable and lead times are short, a *lean strategy with a focus on continuous replenishment* (type I) is suggested. If lead times are long a *lean strategy but with a focus on planning and optimisation* (type II) is proposed. If demand is unpredictable and lead times are short, Christopher et al. (2006) suggested an *agile SC strategy*. If demand is unpredictable and lead times are rather long, the authors suggested a hybrid '*leagile*' SC strategy. Here, a decoupling of a lean and an agile part of the SC through postponement is the best approach. In literature, the terms for these three different strategies are also used and discussed for manufacturing systems.⁴⁷

The classification of SC strategies presented by Christopher et al. (2005) is the basis for the following considerations on the configuration of SC concepts. This classification appears to be suitable for the research problem of CT integration into SC concepts because lead time and demand characteristics are central aspects for the CT concept choice.

⁴⁶ According to Christopher et al. (2008), p. 119.

⁴⁷ e.g., Christopher (2005a); Goldsby et al. (2006); Huang et al. (2002); Startton et al. (2003).

3.1.3 Impact of SC Strategy on the Configuration of SC Sub-Concepts

The SC concept can be understood as the operationalisation and implementation of the SC strategy. The SC strategy determines the SC concept configuration, namely the configuration of the procurement, production and distribution concepts as well as the embedded and linking transport concepts.⁴⁸

SC managers have to make several decisions about how to operationalise SC strategy. They have to decide whether to design processes, structures and management as cost-efficient or responsiveness-oriented.⁴⁹ Thus, the derived SC concept can differ significantly between SCs with the same strategy.

A SC concept can be defined as the interpretation and transfer of the SC strategy to concrete *material and information flow processes*.

*A 'SC concept' defines all relevant technical and organizational structures, planning and control structures as well as management processes to ensure the stable time-, quality- and cost-defined material and information flow on all relevant value adding levels with a focus on meeting the end customer's demand. It is based on the SC strategy and encompasses the configuration of the procurement, production and distribution sub-concepts as well as the embedded and linking logistics and transport concepts.*⁵⁰

The relationship between SC strategy and SC concept is analysed in depth in the following section.

3.1.4 Elements and Structures of SC Concepts

'SC concept' is a collective term for the procurement, production and distribution concepts as well as their embedded and linking transport concepts.⁵¹ The configuration of these sub-concepts determines the information and material flow.

Meyr und Stadtler (2005) published a classification of SCs according to functional and structural characteristics.⁵² They suggested classifying SCs according to the functional characteristics of the procurement type, production type, distribution type and sales type.⁵³ Furthermore, Hofmann (2010) suggested the implementation of the SC

⁴⁸ cf. Heuermann (2002); Hilletoft (2009); Shewchuck (1998).

⁴⁹ cf. Agarwal et al. (2006), p. 21; Hilletoft (2009); Hofmann (2011); Naylor et al. (1999).

⁵⁰ Definition on the basis of Heuermann (2002); Hilletoft (2009); Shewchuck (1998).

⁵¹ according to Hilletoft (2009); Hofmann (2011); Rosenzweig et al. (2003).

⁵² cf. Heuermann (2002).

⁵³ Sales type corresponds to the product and demand characteristics gathered in the SC strategy. cf. section 3.1.3.

strategy in the three functional areas of procurement, production and distribution.⁵⁴ The thesis follows these considerations. It is assumed that a SC concept can be described by the specification of the configuration of the procurement, production and distribution concepts.

The classification according to SC sub-concepts reveals a general problem. The classification of the distribution and procurement concepts implies an actor-specific perspective. The distribution concept of one actor corresponds to the procurement concept of the other actor. Since this aims at the consideration from a non-actor-specific research perspective, in the following section procurement and distribution concepts are analysed separately.

Logistics concepts are embedded and linking elements of the procurement, production and distribution concept. Following the definition of the Council of SCM Professionals (CSCMP), 'logistics' is defined as *'[...] that part of SCM that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements.*⁵⁵ Following this definition, the transport concept is a part of the logistics concept focusing on the material flow aspect and the aspect of spatial transformation.

Production concepts have corresponding activities at the information and material flow level. Transport concepts supply and connect the different production sites. Procurement and distribution processes have a preliminary informational character. Logistics and transport processes concretize procurement and distribution concepts in the form of specific material and information flow processes.

A *transport concept* ensures the material flow between a certain source and a certain destination through the provision of the corresponding capacities of vehicles, personnel, knowhow and overheads.⁵⁶ Usually transport concepts are part of a logistics concept.⁵⁷

⁵⁴ cf. Hofmann (2010).

⁵⁵ cf. Hofmann (2011).

⁵⁶ A transport concept can cover more than one source and one destination. For more details on the structures and elements of transport concepts see section 3.3.1.

⁵⁷ In brief, the *logistics concept* ensures material and information flow along the entire SC. Logistics concepts are characterised by their 'dyadical' character. The logistics concept includes material flow as well as information flow processes, such as warehousing, transport and handling, sorting and order picking, packaging and signing (material flow) as well as order processing (information flow). The logistics concept distinguishes from the definition of the SC concept (cf. section 3.1) because of its dyadical character. This means that the logistics concept considers only two SC actors. cf. CSCMP (2011), p. 9.

*A 'transport concept' defines all relevant technical and organizational structures, planning and control structures as well as management processes to ensure the stable time-, quality- and cost-defined material flow from a specific source to a specific destination.*⁵⁸

Transport concepts can have company-internal as well as cross-company character and can link two or more sites in a SC.

The thesis in hand focuses on the performance-oriented integration of CT concepts. Thus, the following considerations focus on the impact of SC concept configuration on the embedded and linking transport concepts. Logistics processes are interpreted as integrative parts of the procurement, production and distribution concepts and are thus, not separately discussed.

There are several transport concepts in one SC. They are either embedded in the specific concepts or link these by connecting a source and a sink with a material flow. To fulfil this task the performance requirements of the procurement, production and distribution concepts regarding the transport concept must clearly be described. For the structured description of SCP requirements in section 3.2, a framework of seven performance dimensions is developed. The proposed performance dimensions in this framework support can be applied to develop so-called SCP requirements profiles.

There are a number of standardised practices for the design of SC concepts. These standardised practices can be distinguished according to different scopes, application fields and objectives. In the literature and in practice, these practices are usually termed 'logistics concepts', 'SC concepts' or 'delivery concepts'. These standard concepts mean that the same configuration of the procurement, production and distribution concepts or partial aspects of these can be applied to a SC. Thus, the term 'SC concept' must be distinguished between that used in the thesis in hand and that used in the literature and in practice.

The applied standard SC concepts have a direct impact on the configuration of material and information flow processes. For instance, the *concept of industry parks*⁵⁹ is an approach to create proximity between suppliers and buyers and thus, to positively

A 'logistics concept' defines all relevant technical and organisational structures, planning and control structures as well as management processes to ensure the stable time-, quality- and cost-defined material and information flow between two actors.

⁵⁸ Definition developed on the basis of Pfohl (2010), pp. 9; *ibid.*

Definition developed on the basis of Gudehus (2005); Heuermann (2002); Hilletoft (2009); Pfohl (2010), pp. 9.

⁵⁹ For details on the concept of industry parks see for instance Das (2010); Hao et al. (2008); Lambert et al. (2000); Patil et al. , p. 405.

influence the integration of material and information flow processes. Different practices aim at shifting responsibilities and focusing on the corporate core competencies. These are the *VMI concept*⁶⁰ and outsourcing activities, such as the *3PL*⁶¹ and *4PL concepts*⁶². In the field of procurement the alignment of suppliers and buyers' activities such as *Supplier Relationship Management (SRM)*⁶³ and *Customer Relationship Management (CRM)*⁶⁴ are applied. These approaches are closely related to the practices to improve planning and forecasting, such as the *CPFR concept*⁶⁵ as well as the *Efficient Consumer Response (ECR) concept*.⁶⁶ All standardised SC concepts can be represented by the configuration of the procurement, production and distribution concepts as shown in sections 3.2.2 to 3.2.4.⁶⁷

The following sections build on these considerations and discuss the SC concept configuration for the SC strategies presented by Christopher (2005).

3.1.4.1 SC Concept Configuration in a Lean SC

The term 'lean' first appeared in the field of manufacturing in 1990.⁶⁸ In 1996, it was enhanced to the concept of '*lean thinking*'.⁶⁹ The main idea of lean thinking was the elimination of all non-value-adding activities.⁷⁰ The original idea of lean thinking can be drawn back to the *Toyota Production System*. This focuses on the efficient use of resources by level scheduling⁷¹ and states that a value stream is developed that reduces all non-value-adding processes with regard to time.⁷² The measures include the decrease in inventory levels and lot sizes, the elimination of paperwork and redundant processes, the evaluation of suppliers on quality and delivery performance as

⁶⁰ For details on the concept of VMI see for instance Darwish et al. (2010); Kwak et al. (2009); Sari (2008), p. 399; Sennheiser et al. (2008).

⁶¹ For details on the concept of 3PL see for instance Carbone et al. (2005); Ellram et al. (1990); Jayaram et al. (2011), p. 411; Sennheiser et al. (2008); Yao et al. (2010). For the meaning of the 3PL concept for integration of CT concepts see for instance Sheffi (1990) and Bendul et al. (2009).

⁶² For details on the concept of 4PL see for instance Bretzke et al. (2010), p. 47; Bobel et al. (2009); Bobel et al. (2011), p. 414; Sennheiser et al. (2008), p. 413.

⁶³ For details on the concept of CRM see for instance Win (2008), p. 391; Choy et al. (2002), p. 387.

⁶⁴ For details on the concept of SRM see for instance Fricker (2008); Koch et al. (2008), p. 387, 391; Sennheiser et al. (2008).

⁶⁵ For details on the concept of CPFR see for instance Esper et al. (2003); Sari (2008); Sennheiser et al. (2008), p. 385.

⁶⁶ For details on the concept of ECR see for instance Siebel (2002), p. 391.

⁶⁷ The postponement and mass customisation concepts are often termed SC or logistics concepts. However, in the thesis at hand the postponement strategy is discussed in the context of SC strategies (cf. section 3.1.3). The mass customisation concept, as a management approach based on the postponement considerations, is discussed in the SC strategy context, too.

⁶⁸ cf. Mason-Jones et al. (2000).

⁶⁹ cf. Womack et al. (1990).

⁷⁰ cf. Womack et al. (1996).

⁷¹ cf. Christopher et al. (2001); Ohno (1988).

⁷² cf. Hilletoft (2009); Riezebos et al. (2009).

well as the introduction of long-term contracts with a reduced supplier basis.⁷³ Lean principles are suitable for application in a stable and predictable market environment with low varieties of products.⁷⁴

If lead times are short, a '*continuous replenishment*' strategy can be suggested.⁷⁵ Huge production companies apply this concept for retailing customers to ensure a stable product flow based on cooperative and automated order systems. Deliveries are controlled by actual sales. Often, this includes the application of VMI concepts. Here the supplier is responsible for the retailer's inventory holding.⁷⁶ In production, the concept can be applied in the form of the Kanban concept.⁷⁷

If the lead times are long, lean strategies are applied that '*plan and optimize*' the SC most efficiently. Christopher (2008) provided an example from the UK retailer Woolworth. Woolworth sells several million Christmas trees every year. Woolworth sources these from China. Thus, orders are placed more than six months in advance. Nevertheless, because of stable demand, risk is evaluated to be low because of the given experience.⁷⁸

A lean SC strategy causes the configuration of SC sub-concepts with regard to efficiency and for rather high volumes.

The *procurement concept in a lean SC* is characterised by a comparably high share of bought goods.⁷⁹ SRM is characterised by regular, high volume transactions. Thus, supplier relationships are comparably close and are based on a high level of information sharing.⁸⁰ The demand management and forecasting in a lean SC is quantitative and data-driven. Forecasting in a lean SC is accomplished at the finished goods level and the control of variability is comparably easy.⁸¹

The *production concept in a lean SC* is characterised by the manufacturing policy of make-to-stock.⁸² Usually, the decision for a lean SC corresponds with standard products and stable and predictable demand. This means that production is based on forecasts rather than specific customer orders. Production processes are continuous and

⁷³ cf. Naylor et al. (1999); de Treville et al. (2004).

⁷⁴ cf. Hilletoft (2009).

⁷⁵ cf. Christopher (2000), p. 464.

⁷⁶ For details on the concept of VMI see Christopher et al. (2008); Darwish et al. (2010); Kwak et al. (2009); Sari (2008), p. 399; Sennheiser et al. (2008).

⁷⁷ cf. Yao et al. (2010); Dickmann (2009), p. 389.

⁷⁸ cf. Sennheiser et al. (2008), p. 464.

⁷⁹ cf. Balakrishnan et al. (2004); Christopher et al. (2008); Mason-Jones et al. (2000); Naylor et al. (1999); Olhager (2003).

⁸⁰ cf. Sharland et al. (2003).

⁸¹ cf. Mason-Jones et al. (2000); Naylor et al. (1999); Olhager (2003); Stavroulaki et al. (2010).

⁸² cf. Balakrishnan et al. (2004); Choi et al. (2009); Naylor et al. (1999); Ohno (1988); Stavroulaki et al. (2010).

characterised by large volumes and batches.⁸³ Production and assembly are organised in lines and with regard to efficiency.⁸⁴ Product design can also be affected by the SC strategy. In a lean SC, product design is also focused on cost consciousness and efficiency (e.g., the integration of barcodes into the product design of discounters). Lean SCs aim at a balance between efficiency and flexibility.⁸⁵ Here, standardised products or packages are typical.⁸⁶

The *distribution concept in a lean SC* is characterised by the focus on cost-efficiency.⁸⁷ The configuration logistics process and order fulfilment is cost-driven and characterised by high volumes.⁸⁸ Thus, in a lean SC the distribution concept is configured with regard to high transport quantities and comparably low costs.⁸⁹ Demand management is based on quantitative data and algorithmic forecast mechanisms. The number of intermediaries between the manufacturer and end customer is comparably high.⁹⁰

3.1.4.2 SC Concept Configuration in an Agile SC

The term of agility is often connected with responsiveness and the ability to match demand and supply in unpredictable markets.⁹¹ According to Christopher (2000), agility can be defined as:

'Agility is a business-wide capability that embraces organizational structures, information systems, logistics processes and, in particular, mindsets. A key characteristic of an agile organization is flexibility.' (Christopher (2000), p. 37)

The basis of the agility concept can be found in the flexible manufacturing system.⁹² The focus of the agile SC strategy is information flow integration at all SC levels to create high market-responsiveness in order to deal with volatile demand and to avoid lost sales, markdowns and the obsolescence of inventories.⁹³ Thus, the focus of an agile SC strategy is on the informational aspects rather than on efficient physical

⁸³ cf. Agarwal et al. (2006); Sharland et al. (2003).

⁸⁴ cf. Goldsby et al. (2006).

⁸⁵ cf. Lee (2002); Mason-Jones et al. (2000).

⁸⁶ cf. Mason-Jones et al. (2000); Naylor et al. (1999); Olhager (2003).

⁸⁷ cf. Stavroulaki et al. (2010).

⁸⁸ cf. Narasimhan et al. (2006).

⁸⁹ cf. Stavroulaki et al. (2010).

⁹⁰ cf. Choi et al. (2009); Goldsby et al. (2006); Mason-Jones et al. (2000).

⁹¹ cf. Stavroulaki et al. (2010); Agarwal et al. (2006).

⁹² cf. Hilletoft (2009).

⁹³ cf. Christopher et al. (2001).

product flows.⁹⁴ The target is the reduction process and information time at all SC levels.⁹⁵

Christopher (2008) introduced Zara, a Spanish fashion garment manufacturer and retailer, as an example of an agile SC strategy. Zara needs no more than four weeks from design until products are in stores. Cross-functional teams are used to reaching the required high level of flexibility.

An agile SC strategy causes the configuration of SC sub-concepts with regard to responsiveness and rather small volumes.⁹⁶

The *procurement concept in an agile SC* is characterised by the alignment of processes to responsiveness and flexibility.⁹⁷ The purchasing policy aims at the assignment of capacities. Supplier relationships are characterised by rather infrequent and low volume transactions. In comparison with a lean SC strategy, the supplier relationship is a more opportunistic collaboration with more collaborative barriers.⁹⁸ Demand management is based on experience. Forecasting is accomplished at the raw materials level.⁹⁹

The *production concept in an agile SC* is characterised by a manufacturing policy of assembled, made or designed depending on specific customer orders.¹⁰⁰ Thus, the predictability of demand and planning basis for transport concepts is restricted. The production concept in an agile SC is characterised by a make-to-order or design-to-order manufacturing policy. The production system in an agile SC focuses on responsiveness and flexibility and is thus characterised by job shop project and a rather jumbled material flow.¹⁰¹ The focus on flexibility is reflected by individualised and specialised product designs. In an agile SC, the focus on flexibility is reflected by individualised and specialised product designs.¹⁰²

The *distribution concept in an agile SC* focuses on responsiveness and flexibility.¹⁰³ Order fulfilment is time-driven and characterised by rather low volumes.¹⁰⁴ Therefore, the number of intermediaries between the manufacturer and end customer is

⁹⁴ cf. van Hoek (2001).

⁹⁵ cf. de Treville et al. (2004).

⁹⁶ cf. Heuermann (2002), p. 135, 146; Hilletoft (2009), pp. 19.

⁹⁷ cf. Balakrishnan et al. (2004); Mason-Jones et al. (2000); Olhager (2003); Stavroulaki et al. (2010).

⁹⁸ cf. Stavroulaki et al. (2010); Sharland et al. (2003).

⁹⁹ cf. Balakrishnan et al. (2004); Naylor et al. (1999).

¹⁰⁰ cf. Choi et al. (2009); Stavroulaki et al. (2010); Goldsby et al. (2006); Lee (2002); Sharland et al. (2003).

¹⁰¹ cf. Agarwal et al. (2006); Mason-Jones et al. (2000); Storey et al. (2005).

¹⁰² cf. Naylor et al. (1999).

¹⁰³ cf. Stavroulaki et al. (2010).

¹⁰⁴ cf. Swafford et al. (2006).

rather small.¹⁰⁵ The applied forecast mechanisms are rather consultative than being algorithm-based. In a rather agile SC, experience is central for forecasting and thus, for the procurement of raw materials.¹⁰⁶ Demand management generally depends on experience.¹⁰⁷

3.1.4.3 SC Concept Configuration in a Leagile SC

Goldsby et al. (2006) proposed the idea that a lean–agile hybrid can be applied to the provision of base and surplus demand. They suggest answering base demand by a lean SC, whereas demand peaks can be managed in an agile manner.¹⁰⁸

More common is the leagile understanding in terms of the ‘*postponement concept*’. The postponement concept has its roots in the linking of uncertainty costs and risks with product differentiation.¹⁰⁹ The main idea is that uncertainty costs can be avoided or reduced by postponing processes, such as logistics and manufacturing activities until concrete orders are available.¹¹⁰ For a special product it may be sensible to postpone manufacturing,¹¹¹ while for a standard product it may be sensible to postpone distribution processes.¹¹²

Christopher (2008) introduced the example of Hewlett Packard and its strategy for DeskJet printers. A semi-finished product is manufactured in North America and then shipped to four regional centres. These are operated by 3PLs. Here, the products are configured and delivered when customer orders are received.¹¹³

The so-called ‘*logistics postponement*’ aims at the storage of a high inventory level at one or a few strategic locations to postpone the inventory location upstream of the SC as late as possible. This means distribution is delayed as long as possible.¹¹⁴

‘*Manufacturing postponement*’ tends to keep products in a neutral state as long as possible.¹¹⁵ The differentiation point is shifted to the latest possible point by delaying assembly, production, sourcing or even design until there are concrete orders. This

¹⁰⁵ cf. Stavrulaki et al. (2010).

¹⁰⁶ cf. Christopher (2000).

¹⁰⁷ cf. Goldsby et al. (2006); Mason-Jones et al. (2000); Narasimhan et al. (2006).

¹⁰⁸ cf. Stavrulaki et al. (2010).

¹⁰⁹ cf. Goldsby et al. (2006).

¹¹⁰ cf. Bucklin (1965); Pagh et al. (1998); Swaminathan et al. (2003); van Hoek (2001).

¹¹¹ cf. Kisperska-Moron et al. (2010); Lin et al. (2010); Yeung et al. (2007).

¹¹² cf. Brun et al. (2009); Ma et al. (2002). For details see p. 464; Christopher et al. (2008); Huang et al. (2008); Pagh et al. (1998).

¹¹³ cf. Wong et al. (2010).

¹¹⁴ cf. Bowersox et al. (1996); Christopher et al. (2008); Swaminathan et al. (2003).

¹¹⁵ cf. van Hoek (2001).

means the customer decoupling point is moved downstream of the SC as far as possible. Before this point, the SC is forecast-driven, whereas after the decoupling point, the SC is order-driven.¹¹⁶

A leagile SC strategy causes the configuration of SC sub-concepts depending on the location of the customer decoupling point. Upstream of the decoupling point (typically in manufacturing or distribution), processes are designed with regard to efficiency; downstream, processes are designed with regard to responsiveness.¹¹⁷

The *procurement concept in a leagile SC* is characterised by the location of the customer's decoupling point.¹¹⁸ Depending on this, the leagile SC is characterised upstream by rather cost-efficient processes and downstream by rather responsive and flexible processes. Often, VMI concepts are applied.¹¹⁹ The supplier relationships upstream of the order decoupling point have a rather lean character. Thus, demand management, forecasting and variability control are data-driven. The relationships with suppliers are based on regular, high volume transactions.¹²⁰

The *production concept in a leagile SC* is characterised by the manufacture-to-order or assembly-to-order manufacturing strategy.¹²¹ Here, modular designed products or packages are typical. Depending on the customer's decoupling point, the production processes are designed either with regard to efficiency or to flexibility focus.¹²² Thus, in a leagile SC assembly lines and small batch jobs are common.¹²³

The *distribution concept in a leagile SC* depends on the customer's decoupling point.¹²⁴ Upstream of the customer decoupling point, the leagile SC has a rather lean character, whereas downstream of the customer decoupling point the leagile SC has a rather agile character.¹²⁵ Upstream, logistics processes are configured with regard to efficiency, cost and high volumes.¹²⁶ Downstream, processes are characterised by

¹¹⁶ Often, *the concept of mass customisation* is discussed in the context of postponement. The mass customisation concept is a hybrid management approach towards a coincident differentiation and cost leadership strategy based on the postponement concept. The target of the concept is the production of goods and services for a huge market by meeting the differing demands of customers at a cost level that is comparable to standardised products. Therefore, mass production on the basis of a generic product architecture and different product modules is necessary. End products only differ in the specific configuration. The manufacturer aims at the individualisation of products and the interaction with customers. This increases variety and complexity, but increases the quantity of sales. cf. for instance Aigbedo (2007); Bowersox et al. (1996); Dörflinger et al. (2001); Feitzinger et al. (1997).

¹¹⁷ cf. Heurmann (2002), p. 135, 146; Piller (2006), pp. 19.

¹¹⁸ cf. Stavroulaki et al. (2010); Balakrishnan et al. (2004); Mason-Jones et al. (2000); Naylor et al. (1999); Olhager (2003).

¹¹⁹ The VMI concept is in depth discussed in section 3.3.

¹²⁰ cf. Mason-Jones et al. (2000); Naylor et al. (1999); Sharland et al. (2003).

¹²¹ cf. Choi et al. (2009); Goldsby et al. (2006); Lee (2002); Olhager (2003).

¹²² cf. Stavroulaki et al. (2010); Mason-Jones et al. (2000); Olhager (2003).

¹²³ cf. Agarwal et al. (2006); Naylor et al. (1999).

¹²⁴ cf. Goldsby et al. (2006).

¹²⁵ cf. Duclos et al. (2003); Stavroulaki et al. (2010).

¹²⁶ cf. Lummus et al. (2003)

flexibility and responsiveness. Order fulfilment is time-driven and characterised by rather low volumes.¹²⁷ The number of intermediaries between the manufacturer and end customer is rather small.¹²⁸

The following section introduces a classification approach for the description of the SCP requirements of SC sub-concepts regarding the embedded and linking transport concepts. This structure is the basis for the in-depth discussion of the impact of the SC concept configuration on CT integration.

3.2 Development of a Classification of SCP Requirements regarding Transport Concepts

The procurement, production and distribution concepts have specific performance requirements regarding embedded and linking transport concepts. These requirements result from the specific design of material and information flow processes, organisational structure and management processes. The integration of a CT concept (and any other transport concept) into a SC concept demands a clear description and communication of performance requirements. Thus, this section develops a structured description approach for SCP requirements with seven categories for the cross-company communication of SCP in terms of transport concepts. This description approach aims at answering the first research question.

Development of the Classification Approach

A precise description of SCP requirements regarding transport concepts is the basis for the integration of material and information flow processes in SCs. As shown in section 2.1, one problem for the close integration of material and information flows is the missing understanding of processes and operational challenges among SC actors. The operational problems of SC actors, especially including CT, significantly differ (cf. section 2.1.2.3). This section aims to generate clear and consistent performance requirements on transport processes to improve the mutual understanding between the SC and CT actors.

Few publications in the SCM literature deal with transport integration, transport mode and transport carrier choice.¹²⁹ Although several authors have discussed the

¹²⁷ cf. Mohammed et al. (2008).

¹²⁸ cf. Goldsby et al. (2006); Mason-Jones et al. (2000); Stavroulaki et al. (2010).

¹²⁹ cf. Stavroulaki et al. (2010); Meixell et al. (2008)

central attributes of transport mode and transport carrier decision, a general description structure is missing.¹³⁰ Few have discussed transportation mode and carrier choice in terms of SC integration.¹³¹ One central topic in the field is the effect of SC design on transport costs.¹³² However, no publications have covered the targeted design of SCs to enable the integration of a specific transport concept.

In order to understand the specific SCP requirements of shippers 23 interviews with experts from medium-sized and large companies in different industries (building, chemistry, mineral oil, food, retail, steel and mechanical engineering) were conducted. Either a member of the executive board or the chief logistics officer was interviewed. The experts were chosen because of their industry expertise and experience with CT.¹³³ The interview results were structured and concretised based on literature and Internet research.¹³⁴ The methodology does justice to the quality criteria for expert interviews. The interviews were documented, data were triangulated and the experts were integrated into a communicated validation of results.

Seven Categories to Describe SCP Requirements

Seven main categories of shippers' performance requirements were identified. Shippers specify their requirements on transport services primarily regarding (1) time, (2) space, (3) transport quantity and shipment size, (4) product type and (5) costs. Furthermore, there are secondary requirements regarding (6) flexibility and (7) reliability.¹³⁵

Time-related SCP Requirements

A '*time*' dimension gathers all aspects with regard to process and lead times, delivery and pickup dates and frequencies as well as time windows. In particular, transport time is an important key performance indicator for the evaluation of transport services.¹³⁶ Time-related performance requirements must address transport, transshipment, storage, handling and communication times as well as time amounts for associ-

¹³⁰ e.g. Goldsby et al. (2000); Abshire et al. (1991); Bardi et al. (1989); Crum et al. (1997); Danielis et al. (2005); Dobie (2005); Evers et al. (2000); Gibson et al. (2002); Gibson et al. (1993); Kent et al. (2001); Lu (2003); Maier et al. (2002); Naim et al. (2006); Premeaux (2002).

¹³¹ cf. Caplice et al. (2003); Carter et al. (1995); Esper et al. (2003); Liao et al. (2007); Miller et al. (2003); Shinghal et al. (2002).

¹³² cf. Baumgarten et al. (2004); Kasiske (2004); Murphy et al. (1993) mainly focuses on strengthening the image of rail and water carriage.

¹³³ See Appendix A-I for a list of interviews conducted.

¹³⁴ For instance Bortz (2005) presented a compilation of quality criteria. cf. Bortz et al. (2006), pp. 308.

¹³⁵ The term 'secondary' implies that flexibility and reliability can be defined with regard to each other and to the other criteria.

¹³⁶ cf. Nagel (2008); Chen et al. (2004).

ated logistics services. These requirements can be summarised in three main categories: (a) delivery windows,¹³⁷ (b) transport / lead times and (c) delivery frequencies. Depending on the SC strategy, the general characteristics of these criteria can generally be stated. A lean SC strategy is usually reflected by comparably short delivery windows to reduce the resource usage at the delivery site. In agile SCs, the delivery windows are longer since the availability of products in general has priority over the reduction of resource usage. Transport and lead times are long in comparison with agile SCs. A lean SC requires comparably low, but regular delivery frequencies to realise bundling effects. In an agile SC, the delivery frequency must ensure the responsiveness and is thus, more frequent, but irregular. A leagile SC can be characterised by a lean and an agile part depending on the customer's order decoupling point. Thus, the characterisation is indifferent – either short or long. Table 3 - 1 summarises these findings.

dimension	performance criteria	lean	leagile	agile
time	delivery window	short	indifferent; depending on the integration point	long
	transport / lead time	long	indifferent; depending on the integration point	short
	delivery frequency	low / regular	indifferent; depending on the integration point	high / irregular

Table 3 - 1: Time-related SCP requirements depending on the SC strategy.

Space- and Location-related SCP Requirements

All shippers' requirements on the source and destination of the material flow can be summarised by the 'space' dimension. This can be specified by different dimensions. It contains requirements about transport distance between the different pickup and delivery sites (manufacturing, warehouses, transshipment and stores). Additionally, the number of these pickup and delivery sites as well as those of the sources and destinations must be considered. In particular, for the integration of rail, water and air transport the distance to the infrastructure connection is important. This distance can be evaluated by the share between the entire transport distance and the distance to the infrastructure connection.

A lean SC is characterised by comparably long transport distances and distance to infrastructure, whereas in an agile SC distances must be shorter to increase respon-

¹³⁷ The criterion 'delivery window' was also suggested by Frohlich et al. (2002).

siveness. The length of transport distances usually corresponds to the number of sources and destinations. In a lean SC, the number of sites is usually lower than that in an agile SC. These can be described, for instance, by the places of loading and unloading, specific capacities (for instance, for transshipment, buffering, storage), equipment and layout. Table 3 - 2 summarises the findings on space-related performance requirements.

dimension	performance criteria	lean	leagile	agile
space	transport distance	long	indifferent depending on the integration point	short
	distance to infrastructure connection	long	indifferent depending on the integration point	short
	no. of sources and destinations	low	indifferent depending on the integration point	high

Table 3 - 2: Space-related SCP requirements depending on the SC strategy.

The ‘*transport quantity and shipment size*’ dimension is a central aspect of the design of a transport concept. In a lean SC, transport quantities and the sizes of the shipments are comparably high. In an agile SC, transport quantities and shipment sizes are rather small. Table 3 - 3 summarises the findings on shipment size and transport quantity SCP requirements.

dimension	performance criteria	lean	leagile	agile
transport quantity / shipment size	--	high	indifferent depending on the integration point	low

Table 3 - 3: Shipment size and transport quantity SCP requirements depending on the SC strategy.

The ‘*product type*’ dimension gathers all product-specific requirements. The central requirements of a transport service result from the type of goods (e.g., aggregate, chilled, hazardous, fragile etc.), goods mix and transport quantity. These criteria directly affect the requirements for load carriers (size, number, weight, design, etc.) as well as handling and storing equipment. Thus, the need for certain types and designs of loading ramps, vendor docks and sidings, handling and transshipment equipment, such as stackers, forklifts, reachstackers and cranes can be summarised under the ‘product’ category. The meaning of the ‘*product type*’ dimension has been highlighted by several authors.¹³⁸ In a lean SC, products are usually standard with no specific requirements. In an agile SC, products can be rather special. In a leagile SC, product type depends on the point in the SC, but often products are of modular structure.

¹³⁸ cf. Christopher (2000); Devaraj et al. (2007); Frohlich et al. (2001); Jayanth et al. (2010).

Product type is a central requirement in terms of transport concepts. The decision about a certain product type is strategic in nature (cf. section 3.1). Thus, for the discussion of the impact of SC sub-concept configuration it is assumed that product type cannot be influenced by the adaptations to sub-concepts. Table 3 - 4 summarises the findings on product type-related SCP requirements.

dimension	performance criteria	lean	leagile	agile
product type	--	standard	standard, special, modular	special

Table 3 - 4: Product type-related SCP requirements depending on the SC strategy.

The 'cost' dimension captures requirements regarding desired target costs, process costs and transaction costs. Shippers' requirements regarding cost performance criteria can be expressed, for instance, by transport costs, costs per transport or transport unit and emissions per transport unit or kilometre. Shippers have certain requirements around risk sharing, devolution of property, incoterms,¹³⁹ insurance and emergency aspects, which can be summarised in the 'cost' category. Different authors have confirmed the meaning of costs from the shippers' points of view to be key performance indicators within SCs.¹⁴⁰ In particular, the meaning of inventory and inventory turns has been analysed in several publications.¹⁴¹ In a lean SC, the share of transport costs and entire turnover is comparably high. Thus, the cost pressure is distinctively higher than that in an agile SC. Here, the share of transport costs is comparably low and thus, transport costs are usually not central to the SC design. Table 3 - 5 summarises the findings on the cost-related SCP requirements.

dimension	performance criteria	lean	leagile	agile
cost	transport cost / turnover	high	medium	low

Table 3 - 5: Cost-related SCP requirements depending on the SC strategy.

'Flexibility' aspects can be discussed with regard to each of the previous categories. Describing the requirements for transport concepts, especially flexibility regarding time, space and transport quantity, is central. Flexibility requirements can be defined regarding spatial aspects such as the variety of final destination and origin. Flexibility can also be stated with regard to delivery times, delivery frequency and short-term changes as well as with regard to the handling of different product types and quanti-

¹³⁹ Incoterms are international rules for typical trade contracts. Following Rosenzweig et al. (2003).

¹⁴⁰ cf. Chen et al. (2004); Devaraj et al. (2007); Gabler (2011); Poirier et al. (2004).

¹⁴¹ See for instance Frohlich et al. (2001); Ranganathan et al. (2004); Rosenzweig et al. (2003).

ties. Often, the term '*responsiveness*' is used for external flexibility. It stands for flexibility regarding different product types, the product mix, volumes, processes and destinations.¹⁴² This is supported by several authors, for instance by and Chen & Huang (2004). Flexibility is necessary to deal with demand uncertainties,¹⁴³ variability,¹⁴⁴ product variety¹⁴⁵ and lead time compressions.¹⁴⁶ For the integration of CT into SC concepts, three main flexibility dimensions can be distinguished. Each can be described by the variance and frequency of variances. In a lean SC, the flexibility of the criteria regarding time (e.g., shorter lead times, delivery times), quantity (e.g., more or less transport quantities) and space (e.g., different pickup/delivery sites) must be comparably low. In an agile SC, the flexibility in all dimensions must be high to ensure a high level of responsiveness. In a leagile SC, the flexibility requirements depend on the specific location in the SC. Table 3 - 6 summarises the findings on the flexibility-related SCP requirements.

dimension	performance criteria	lean	leagile	agile
flexibility	time (variance/ frequency)	low	indifferent depending on the integration point	high
	quantity (variance / frequency)	low	indifferent depending on the integration point	high
	space (variance /frequency)	low	indifferent depending on the integration point	high

Table 3 - 6: Flexibility-related SCP requirements depending on the SC strategy.

'*Reliability*' levels can be defined regarding time (lead time, time window, etc.) and product quality. The meaning of delivery reliability has been discussed in several publications including Rosenzweig et al. (2003), Chen & Huang (2004), Devaraj et al. (2007) and Poirier & Quinn (2004). For the thesis in hand, adherence to schedules and product quality are defined as the relevant reliability requirement dimensions. Adherence to schedules can be expressed as the ratio of punctual and delayed transport. Product quality can be expressed as the ratio of transport without quality complaints and transport with quality complaints. In a lean SC, based on predictability and the reduction of inventories the reliability dimensions are of high importance. Although reliability is important for leagile and agile SCs too, the required level is comparably lower. Table 3 - 7 summarises the findings on the reliability-related SC requirements.

¹⁴² cf. Zhu et al. (2002), p. 1144.

¹⁴³ cf. Fisher et al. (1994); Griffiths et al. (2000); Harrison (1996); Reichhart et al. (2007).

¹⁴⁴ cf. Harrison (1996); Krajewski et al. (2005).

¹⁴⁵ cf. Berry et al. (1999); Inman et al. (1997); MacDuffie et al. (1996).

¹⁴⁶ cf. Randall et al. (2001); McCutcheon et al. (1994), p. 1144.

dimension	performance criteria	lean	leagile	agile
reliability	adherence to schedules	high	medium	medium
	product quality	high	medium	medium

Table 3 - 7: Reliability-related SCP requirements depending on the SC strategy.

Table 3 - 8 summarises the considerations in the form of SCP requirements profiles for lean, leagile and agile SCs.

performance criteria	dimension	lean	leagile	agile
time	delivery window	short	indifferent	long
	transport time	long	indifferent	short
	delivery frequency	low / regular	indifferent	high/ irregular
space	transport distance	long	indifferent	short
	distance to infrastructure connection	long	indifferent	short
	number of sources and destinations	low	indifferent	high
transport quantity / shipment size		high	medium	low
product type		standard	indifferent (standard, special, modular)	special
cost	transport cost / turnover	high	medium	low
flexibility	time (variance of lead time/ rate)	low	indifferent	high
	quantity (variance / rate)	low	indifferent	high
	space (variance / rate)	low	indifferent	medium
reliability	adherence to schedules (level / rate)	high	medium	medium
	quality (level / rate)	high	medium	medium

Table 3 - 8: SCP requirements profiles derived from SC strategy.

The following section introduces the structures and elements of the procurement, production and distribution concepts for different SC strategies. These considerations serve as the basis to identify the ‘*designable*’ aspects of the SC for the targeted adaptation of the SC concept to enable performance-oriented CT integration.

3.3 Configuration of SC Concepts

This section discusses the elements and structures of SC concepts and derives the specific performance requirements regarding the embedded and linking transport concepts. In a first step, the general structures and elements of SC sub-concepts are introduced. In a second step, a structured description of SCP requirements regarding the procurement, production and distribution concepts of the embedded and linking transport concepts is developed. This approach is the basis for the discussion of different SC sub-concept configurations and the specific impact on the applicability of CT concepts. Therefore, it is assumed that product- and demand-related criteria are not alterable to influence the integration of a certain CT concept.

3.3.1 Transport Concepts as Linking and Embedded Elements of SC Concepts

This section addresses the structures and elements of transport concepts as linking and embedded elements of the procurement, production and distribution concepts. In the thesis in hand, transport concepts are interpreted as the central elements of SC concepts. They significantly influence overall SCP. Transport concepts must meet the SCP requirements of the procurement, production and distribution concepts. Thus, this section provides a general understanding of transport concepts by introducing the main strategies and structures. Therefore, it is necessary to take the transport operator's perspective regarding the transport concept- Usually, 3PLs or carriers are responsible for the linking and embedded transport processes of procurement and distribution concepts.¹⁴⁷ Outsourcing production internal transport processes is rather uncommon.¹⁴⁸

Structure and Strategies of Transport Concepts

Transport concepts accomplish the material flows within procurement, production and distribution concepts. Often, the transport concept is part of a wider logistics concept (cf. section 3.1). Transport planning encompasses different sub-problems. Fleet planning means the optimal composition of the vehicle fleet regarding vehicle type, capacity and number. Vehicle action planning is based on a given vehicle fleet and considers the optimal allocation of vehicles and customers.

A *transport strategy* is the operation strategy of transport concepts. It determines how the transport control unit steers the waiting transport orders, guides the transport vehicles to the destinations and controls the processing at the different sites in a SC concept.¹⁴⁹ According to Gudehus (2005), the choice of the optimal transport strategy is often the best way to optimize a logistics concept.¹⁵⁰ Usually, the adaptation of the transport concept is faster and cheaper than is investing in new technological solutions. Transport strategies influence the complexity of the transport network, the performance of the existing transport system, the number of vehicles and the functionality and safety of the transport system.

¹⁴⁷ cf. Stölzle et al. (2011), pp. 223. For details on the concept of 3PLs see Reichhart et al. (2007); Carbone et al. (2005); Ellram et al. (1990); Jayaram et al. (2011), p. 411; Sennheiser et al. (2008). For the meaning of the 3PL concept for the integration of CT concepts see for instance Sheffi (1990) and Bendul et al. (2009).

¹⁴⁸ cf. Stölzle et al. (2011), pp. 223.

¹⁴⁹ cf. Bobel et al. (2009), p. 823.

¹⁵⁰ cf. Gudehus (2005), p. 823.

Gudehus (2005) suggested the classification of transport concepts according to different types of transport strategies.¹⁵¹ The *station strategy* determines the way to process waiting transport orders at different sites for loading and transport to the destination. Processing can be accomplished according to a defined sequence, for instance the first-come-first-served rule. This means that arriving transport orders are processed in their sequence or on arrival. Furthermore, the different priority rules (e.g., for certain products or destinations and rush orders) are applied. By applying a free processing sequence, all orders for one destination or driving direction are gathered (independent of their arrival sequence) until the capacity limit or a scheduled time of departure is reached.¹⁵²

The processing of transport orders according to a defined sequence, such as first-come-first-served, is rather inappropriate for accomplishment by CT. The unforeseeable sequence of transport goods and destinations prevents the usage CT because of the missing time in advance for the dispatching of rail transport and transshipment processes. This means that in a free processing sequence the bundling effects support CT integration, especially in combination with a transport schedule, since here the necessary planning basis is given with defined destinations and transport times.

Loading Strategy

The bundling of loads improves capacity usage and thus, reduces costs, but it means additional waiting times.¹⁵³ There are two different *strategies for the loading of transport vehicles*: the one-destination and mixed-destination strategy. This means either the transport vehicle loads only goods for one destination or for multiple destinations on the same transport route. Furthermore, transport without and with multiple loadings are distinguished. Either only the completely empty transport vehicle is reloaded or the transport vehicle is reloaded on the transport route if there is free capacity.¹⁵⁴ This strategy improves the capacity usage of the transport vehicle.

Generally, the loading strategy does not influence the applicability of CT concepts as long as rail transport is accomplished with complete loading. However, depending on the situation-specific SC concept configuration and SCP requirements regarding the

¹⁵¹ cf. Ibid., p. 824. Gudehus uses the term of '*transport strategy*'.

¹⁵² cf. Ibid., p. 823.

¹⁵³ cf. Ibid., p. 824.

¹⁵⁴ cf. Ibid., p. 824.

transport concept, it can be assumed that the fewer the stations on the transport route the more time buffers can be accessed for the integration of CT into the specific SC concept.

Transport Route Strategy

The *transport route strategy* determines the *sequence of destinations* for a certain transport vehicle and thus, sets the transport route. For instance, the transport route strategy depends on the shortest transport distance, the shortest transport time or lowest transport costs. In addition, strategies aiming at a high level of capacity usage are applied. Schedule strategies determine the transport processes according to a determined transport schedule. Usually, a transport schedule is configured to minimize transport distances and maximize capacity utilisation. For transport systems with only a few relations the driveways and roundtrips with the shortest distances, driving times or lowest costs can be found by full numeration and the comparison of all possible solutions. For complex transport networks, this optimisation is usually not possible. Operation research has developed different heuristic approaches for the approximation of the optimal solution.

Following the considerations above, the availability of transport schedules supports CT integration depending on the situation-specific SCP requirements regarding the transport concept. Transport concepts without a predefined sequence of transport sites prevent the integration of CT because of the missing planning time in advance. The transport structure can be understood as the counterpart of the loading strategy from a shipper's or from the good's perspective.

Transport Structure

Pfohl (2005)¹⁵⁵ classified different transport concepts according to the structure of the transport chain. An unbroken transport chain is accomplished without changing the transport vehicle and directly joins the source and destination. FTL means that the entire shipping space is filled. LTL means that parts of the shipping space are booked by different shippers.¹⁵⁶ Although this notation implies the reference to road transport, these considerations regarding full and partial loading can be transferred to other modes. Rail, water and air cargo transport can accomplish stopovers to load or

¹⁵⁵ cf. Ibid., pp. 164.

¹⁵⁶ This differentiation is common for all transport modes.

deload shipments. Figure 3 - 2 summarises the considerations in a schematic figure.

A so-called broken transport chain means that the shipper and consignee change the transport vehicle. According to Pfohl (2005), this can be termed CT in the broadest sense.¹⁵⁷

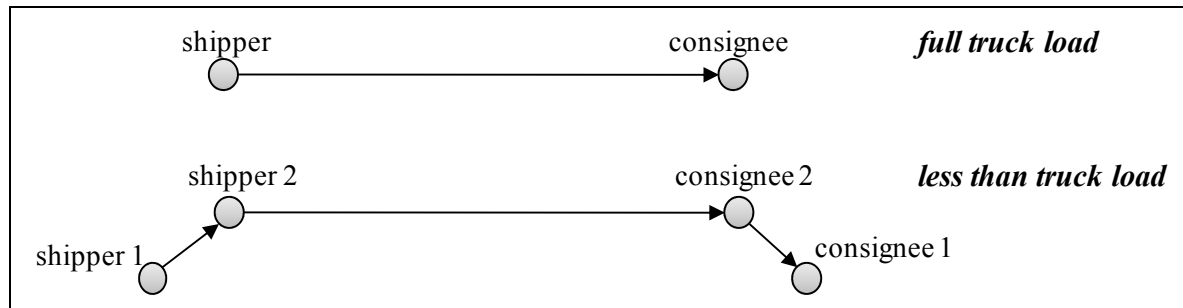


Figure 3 - 2: Transport structure for full and less than full truckloads.¹⁵⁸

Relation transport is defined as direct FTL transport between shipper and consignee without transshipment processes. This type of delivery can, for instance, be found in JIT and JIS concepts with high transport frequency and high transport vehicle utilisation.¹⁵⁹ Often, the relationship between returned empties and goods of 1:1 has defined delivery windows. A relation transport corresponds to a transport route strategy with only one destination.

The *milkrun concept* is a specific type of the relation transport concept for distribution and procurement concepts. Usually, within defined time windows partial loads are bundled on a defined transport route and delivered to the consignee without transshipment processes. Additionally, the concept includes the return of empty load carriers. Likewise, the milkrun concept can be applied to the distribution of goods starting from a central shipper. This allows the improvement of the capacity utilisation of transport vehicles and an increase in transport frequency. Thus, the concept supports the short-term transport optimisation and reduction of transport costs.¹⁶⁰ A milkrun concept corresponds to a transport route strategy with several destinations.

Packaged goods transport is a type of broken transport since here more than one transport vehicle is used. Figure 3 - 3 shows the schematic structure of a transport network for packaged goods transport.¹⁶¹

¹⁵⁷ cf. Pfohl (2010), p. 165.

¹⁵⁸ cf. Ibid., p. 11.

¹⁵⁹ cf. Müller et al. (2009), p. 29; Iskan (2009), p. 626; Schorb et al. (2007), p. 10.

¹⁶⁰ cf. VDA (1997), p. 31; Iskan (2009), p. 2.

¹⁶¹ For details different freight or transport networks see for instance Gudehus (2005), pp. 956; Alicke (2003).

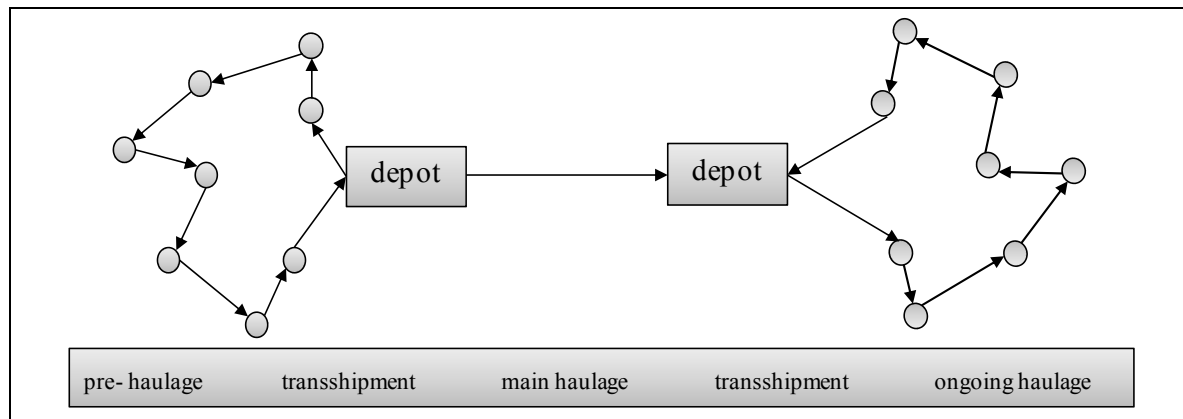


Figure 3 - 3: SC structure for a packaged goods transport.¹⁶²

Pfohl (2005) also distinguished between broken transport in the proper meaning of the word, namely including a change of load carrier and often including storing and further handling processes, and CT, namely without a load carrier change.¹⁶³ However, the term ‘CT’ is in this publication not restricted to the combination of road and rail transport. Here, the author distinguishes between piggyback services and container services.¹⁶⁴

For the integration of CT services, the transport structure is central. Different structures require different CT concept types. CT concept types with regard to the structure of material and information flows are introduced in section 3.4.

3.3.2 Impact of Procurement Concepts on the Configuration of Transport Concepts

This section clarifies the elements and processes of procurement concepts to identify adaptation points for the performance-oriented integration of CT into SCs. In a first step, the meaning of the procurement concept for SCP is worked out. In a second step, the structures and processes of the procurement concept are described. Furthermore, the impact of the SC strategy on the design of the procurement concept is discussed. Finally, classification criteria for procurement concepts are discussed and criteria influencing the SCP requirements regarding the embedded and linking transport concepts are identified.

¹⁶² cf. Wildemann et al. (2011), p. 12.

¹⁶³ cf. Müller et al. (2009), pp. 164.

¹⁶⁴ For further details on the structure and characteristics of CT services see section 2.2.

3.3.2.1 Meaning of the Procurement Concepts for SCP

The procurement concept defines the planning, control, implementation and monitoring of all activities related to procurement and determines the corresponding structures, resources and management processes.¹⁶⁵ Recently, procurement processes have gained strategic meaning. This has resulted from the dependency of production and distribution concepts on the interruption-free supply with goods.¹⁶⁶

The procurement concept significantly influences the cost structures of manufacturing and retail companies. Often, the share of purchasing costs is more than 50% of a product's total costs.¹⁶⁷ *Strategic procurement management* aims at the development of capabilities as well as procurement activities by means of procurement market investigation, procurement controlling and benchmarking.¹⁶⁸ The thesis in hand focuses on *operative procurement management*.¹⁶⁹ This encompasses the recognition of demand, identification and choice of suppliers, order processing and controlling and accounting.¹⁷⁰

The *target system* of procurement concepts depends on the procurement object and the resulting requirements. General targets are cost reduction, differentiation and the security of supply.¹⁷¹ *Cost reduction* encompasses the reduction of acquisition prices, transport, warehouses, provisions, processes, overhead costs as well as material costs. This also includes debt service costs as well as out-of-stock costs.¹⁷² *Differentiation* means the improvement of product and process quality,¹⁷³ for instance by standards for suppliers, the improvement of service levels and lead times as well as the participation in the supplier's knowhow and image. The *security of supply* focuses on the increase of adherence to schedules, a high level of delivery availability,¹⁷⁴ distribution of risk and increase in the market share of the purchasing market. Increasingly, sustainability and environmental orientation influence the target system of procurement. As a result, companies increasingly choose suppliers that are ecofriendly.¹⁷⁵ Further targets include the supply-based diversification of the protection of inde-

¹⁶⁵ Following the definition of Pfohl (2010) and the definition of SC concepts (section 3.2.1).

¹⁶⁶ cf. Cooper et al. (1997); Ursel et al. (2010).

¹⁶⁷ cf. Koppelman (2002).

¹⁶⁸ cf. Ursel et al. (2010), pp. 56; Arnold (1997), p. 32.

¹⁶⁹ cf. Piontek (1994), p. 96.

¹⁷⁰ cf. Hamm (1997), pp. 99.

¹⁷¹ cf. Ibid., pp. 66.

¹⁷² See Ibid., p. 32.

¹⁷³ See for instance Piontek (1994), p. 32.

¹⁷⁴ cf. Grimm et al. (2010); Peters (2010); Piontek (1994), p. 32.

¹⁷⁵ See for instance Piontek (1994).

pendence and flexibility as well as the increase in vertical integration.¹⁷⁶

The procurement concept must be carefully adjusted and linked with the other distribution, production and procurement concepts in the SC. This ensures the stable and reliable supply of the production concept with raw materials and supplies, parts and externally manufactured goods. The procurement concept is central for each SC concept because it ensures the operability of the production systems and thus that end customers are supplied with goods.

The procurement concept is concretised at the material flow level by transport and logistics processes. Transport processes convert purchasing processes into specified material flows for the production concept's supply or direct distribution. Furthermore, warehousing, transshipment and additional logistics services have a special importance.

The following section builds on these general findings and introduces the basic structures and processes of procurement concepts. The section aims at a general understanding how the configuration of the procurement concept influences SCP requirements regarding the embedded and linking transport concepts.

3.3.2.2 Structures and Processes of Procurement Concepts

Procurement encompasses all corporate activities for the supply of goods necessary to realise corporate targets. Procurement markets obtain services, production facilities (fixed capital goods), materials (raw materials and supplies, semi-finished goods) and trade goods. Usually, these tasks are accomplished by a purchasing department.¹⁷⁷

Applied standardised concepts include the concept of industry parks to increase the proximity between buyer and supplier.¹⁷⁸ The SRM concept aims at the process-oriented evaluation and choice of suppliers from a customer's point of view. The evaluation of the relationship is accomplished according to supplier lifetime value.¹⁷⁹ The CPFRR concept focuses on the improvement of efficiency and effectiveness by means of standardisation and improved planning and forecasting.¹⁸⁰

¹⁷⁶ cf. Kudla et al. (2011), p. 32.

¹⁷⁷ cf. Piontek (1994), p. 343.

¹⁷⁸ For details on the concept of industry parks see for instance Das (2010); Hao et al. (2008); Lechner et al. (2008); Patil et al. , p. 405.

¹⁷⁹ For details on the concept of SRM see for instance Fricker (2008); Koch et al. (2008), p. 387, 391; Sennheiser et al. (2008).

¹⁸⁰ For details on the concept of CPFRR see for instance Esper et al. (2003); Sari (2008); Sennheiser et al. (2008), p. 385.

The procurement process can be divided into seven sub-processes to provide the required materials and goods in the demanded quality and quantity at the desired site and time point and at competitive prices. (1) The production and distribution departments (in retail) give a material requisition to the purchasing department. After the (2) supplier makes a choice, an (3) order is made. The goods are (4) transported and (5) received by the purchasing company. The delivery is (6) confirmed and the accounting department (7) verifies the invoice and initiates the payment transaction.¹⁸¹

The *procurement strategy* classifies procurement goods according to supply risk. This risk definition encompasses the number of suppliers, substitute possibilities, risks of storage as well as possibilities of in-house production. Furthermore, an evaluation of the procurement volume, namely using an ABC analysis, is accomplished.¹⁸² Within a four-field matrix, four different procurement product types can be distinguished. From these a general procurement strategy can be derived.

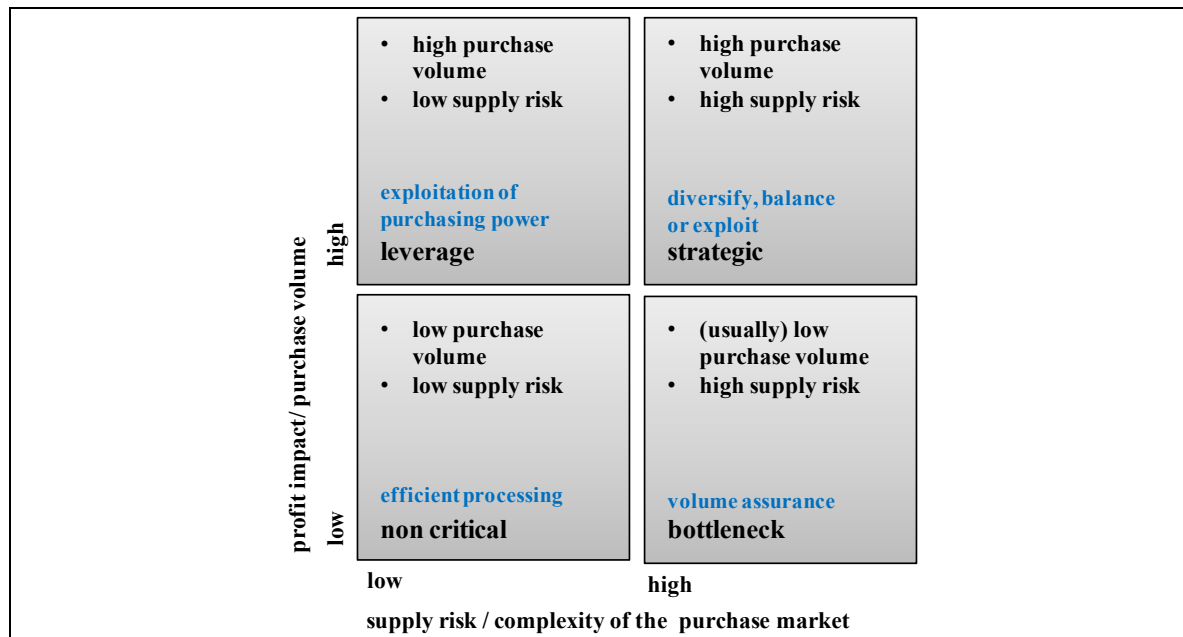


Figure 3 - 4: Generic procurement strategies according to supply risk and profit impact.¹⁸³

Products with high purchase volumes and low supply risks, so-called 'leverage' goods, are usually standardised objects purchased from a high number of suppliers. A supplier switch can be accomplished easily. To increase corporate success aggressive behaviour on the procurement market is typical to increase and stabilise demand

¹⁸¹ cf. Siebel (2002), p. 13.

¹⁸² cf. Arnold (1997), p. 133.

¹⁸³ cf. Ibid.; Gudehus (2005), p. 92.

power and to activate the competition on the procurement market (active procurement marketing).¹⁸⁴

The procurement of *goods with low volumes and low risks*, so-called '*non-critical*' goods, for instance standard parts, which are technically mature and standardised,¹⁸⁵ should be cost efficient and require low resources. Adaptation points for these types of procurement goods are the reduction of order processing, the centralisation of the purchasing function or the outsourcing of procurement activities.¹⁸⁶

Procurement goods, characterised by *low procurement volumes and high supply risks*, so-called '*bottleneck*' goods, should focus on the stabilisation of supply, either by warehousing or by the substitution of products or new suppliers. Usually, there is a restricted number of suppliers. However, the resource intensity to handle these types of goods should be restricted because of the low procurement level.¹⁸⁷

For products with *high procurement volumes and high supply risks*, so-called '*strategic*' goods, a strategic solution is required that focuses on the vertical and technology-based cooperations with selected suppliers. These selected suppliers are integrated into research and development activities, too. The resulting long-term partnership leads to a reduction in planning and disposition effort for the procurement of goods.¹⁸⁸

The integration of CT simplifies as the higher and more stable transportation volumes become. Thus, CT solutions are initially suitable for 'leverage' and 'strategic' goods. However, the procurement strategy for strategic products is characterised by diversification, exploitation and balancing activities in order to increase the independence on single suppliers and increase the security of supply. Thus, the required transport processes are rather unstable and change regarding relations and transport quantities. Thus, the suitability for the integration of CT for the procurement of strategic goods is restricted. 'Leverage' goods with high transport quantities and low supply risks, and thereby rather stable supplier relations, are most suitable for CT integration.

The specific configuration of the procurement concept is significantly influenced by product type, market demand and SC strategy. The following section clarifies the

¹⁸⁴ cf. Canie et al. (2005), p. 92.

¹⁸⁵ e.g., connection elements, semi-finished products, stationary, paper etc.

¹⁸⁶ cf. Arnold (1997), p. 91.

¹⁸⁷ cf. Ibid., p. 92.

¹⁸⁸ cf. Ibid., p. 92.

relationship between the SC strategy and procurement concept configuration.

3.3.2.3 Classification and Configuration of Procurement Concepts – Identification of Design Variables relevant for CT Integration

This section addresses the classification criteria for procurement concepts with regard to the integration of CT. In particular, the impact of different classification criteria on SCP requirements regarding the CT concept is discussed.

There are multiple approaches to the classification of procurement concepts.¹⁸⁹ However, for the thesis in hand it is critical to identify not only classification criteria, but initial points for the performance-oriented integration of CT into SC concepts. This means so-called '*design variables*' have to be identified. These criteria can be configured independent of product type and SC strategy. They are starting points to adapt the SC concept and to change SCP requirements with regard to the embedded and linking transport concepts.

Arnold (1997) identified procurement subject, procurement type, product characteristics, product value, aggregate phase, market size and demand predictability as criteria for the classification of different procurement concepts.¹⁹⁰ However, in the thesis in hand, it is assumed that product- and demand-related characteristics are not changeable and thus, not suitable for the adaptation of SC concepts with regard to CT integration.

Furthermore, Arnold (1997) identified supplier choice and number of sources, procurement area, procurement time and delivery agreements, namely the agreed incoterms¹⁹¹ as classification criteria for procurement concepts.¹⁹² These criteria are relevant for the integration of CT into SC concepts.

Table 3 - 9 gives an overview of the classification criteria that are relevant to the integration of CT into SC concepts.

¹⁸⁹ cf. Ibid., p. 92; Meyr et al. (2005).

¹⁹⁰ cf. Stadler (2005), p. 93. The specific characteristics often correspond to one of the general procurement strategies.

¹⁹¹ cf. Arnold (1997); ICC (2010b).

¹⁹² cf. Gabler (2011), p. 96.

classification criteria	characteristics			
supplier choice	sole	single	dual	multiple
procurement area	local	domestic		global
procurement time	stock sourcing	demand tailored sourcing		single sourcing
incoterms	see Figure 3 - 5			

Table 3 - 9: Classification criteria for procurement concepts with regard to the impact on transport concepts.¹⁹³

The impact of the different classification criteria on the embedded and linking transport concepts is discussed in the following. In a first step, the classification criteria and typical characteristics are introduced. In a second step, the impact of different characteristics on the seven identified SCP requirement categories developed in section 3.2 is clarified.

Supplier Choice

Supplier choice influences the number and locations that must be covered by the transport concept.¹⁹⁴ Furthermore, it influences the total inventory level and can also affect SCP depending on the reliability of the supplier. Supplier choice can be utilised to influence SCP requirements. Thus, it directly influences time-related performance aspects, namely delivery windows, lead times and delivery frequency depending on the location and reliability of the supplier. Total transport distance, distance to the infrastructure connection (e.g., the next highway or CT terminal) and number of sites on the transport route are also influenced by supplier choice. Depending on the location and delivery frequency, shipment size may be affected, too. These aspects also influence transport costs. Arnold (1997) stated the importance of the SC concepts' flexibility (regarding time, transport quantities and space) and reliability regarding adherence to schedules and product quality.¹⁹⁵

In general, the fewer suppliers there are in the procurement concept, the higher are transport volumes and bundling effects. Thus, depending on the situation-specific configuration of the SC concept a low number of suppliers supports the integration of CT. However, smaller and irregular transport volumes with rather long lead times could be delivered by CT networks.

¹⁹³ Compilation in accordance to Arnold (1997), pp. 93; Ibid., pp. 311.

¹⁹⁴ Supplier choice corresponds to the procurement strategy introduced in the previous section.

¹⁹⁵ cf. Arnold (2002), pp. 93; Arnold (1997), p. 311.

Procurement Area

The *procurement area* is of special meaning for transport mode choice. Global suppliers require long distance transport modes such as ocean carriers or air cargo. Usually, rail and road transport are common for local and domestic suppliers. Local sourcing means that a spatial proximity to the supplier is assumed. Typical examples are industry parks¹⁹⁶ or the in-house production of suppliers.

Economic advantages of CT can be realised the better, the longerlong transport distances are. Thus, domestic and global procurement areas (ongoing haulage after main haulage by sea or air transport) are in particular suitable for CT integration. The integration of CT into a distribution concept with local procurement area depends on the extent of the area and distance to the customer.

Procurement Time

Procurement time is central to the available advance of time for the physical procurement process. Stock sourcing aims at the realisation of economies of scale and security of supply and is especially suitable for parts with low value and high transport quantities. This type requires singular, but huge transport and logistics capacities. Demand tailored sourcing is driven by customer orders and thus, is often unspecific. It means that a coordination of supplier and buyer is necessary. The introduction of regular transport with huge transport volumes is often not possible. Singular sourcing is characterised by high and regular demand.¹⁹⁷ Here, rolling demand planings are applied. Therefore, the customer-oriented product is ordered immediately before delivery, but the transport concept can be configured based on a stable basic demand.

A long procurement time and procurement from stock positively influence the applicability of CT. However, the variant of the product does not necessarily influence transport. Thus, in demand tailored sourcing the integration of CT is also possible if transport quantities and relation can be sufficiently predicted. In a JIT or JIS concept, the implementation of CT is complicated because of short lead times and the requirements for high transport frequencies.

¹⁹⁶ For details on the concept of industry parks see Arnold (2002); Das (2010); Hao et al. (2008); Patil et al. , p. 405.
¹⁹⁷ Often here the standardised JIT concept is applied.

Incoterms

'Incoterms' is the abbreviation for 'international commercial terms'. The International Chamber of Commerce (ICC) publishes a series of predefined commercial terms for international commercial transactions.¹⁹⁸ The terms serve to clearly communicate the tasks, costs and risks of transport and delivery. Although incoterms were introduced for cross-country transport, the following considerations can be transferred to delivery agreements within one country.

The target of usage is the reduction of uncertainties resulting from different interpretation of such terms in different countries. Incoterms were first published in 1936. They are updated periodically. The eighth version was published in January 1, 2011. Figure 3 - 5 gives an overview of the latest incoterms regarding documentation, risks and cost agreements (version 2010).

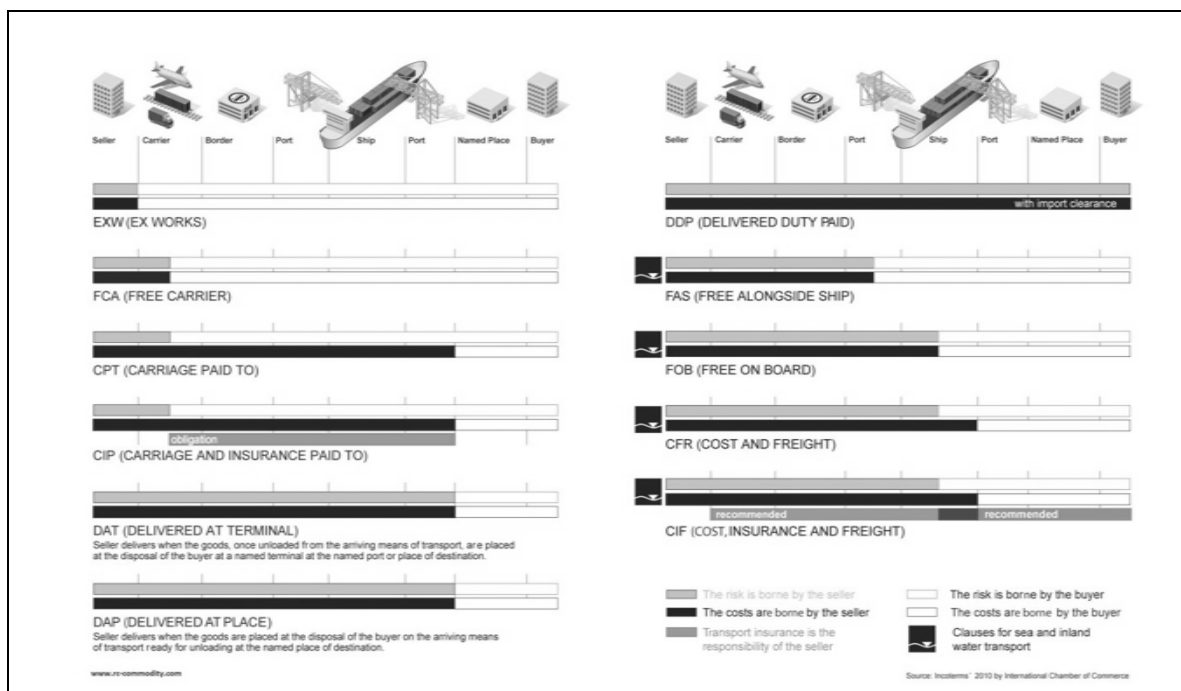


Figure 3 - 5: Overview of incoterms 2010.¹⁹⁹

Recently, there have been 11 incoterms. Figure 3 - 5 shows these incoterms in ascending order of the responsibility of the vendor. The usage of incoterms is voluntary and requires no contractual agreement. In practice, most commonly used incoterms are 'ex works' (EXW), 'free on board' (FOB), 'cost, insurance and freight' (CIF) and

¹⁹⁸ cf. ICC (2010a).

¹⁹⁹ cf. ICC (2010b); (illustration according to <http://www.rc-commodity.com/info-center/incoterms.html>).

'delivered duty paid' (DDP).²⁰⁰

Incoterms directly influence the cost distribution in the SC. This includes the cost of risks, transport, handling and warehousing as well as customs, duties and taxes. Incoterms thus indirectly impact all other SCP requirements since the distribution of responsibilities includes the decision of the operator SC. Thus, it can be assumed that the change in incoterms may especially influence time flexibility as well as reliability regarding product quality, since the risk is variously distributed.

The agreed incoterms do not directly influence material flow processes, but rather the reliable actor for the transport, the property situation and the risk allocation, costs and documentation obligations. In general, depending on the SC concept configuration, an incoterm that shifts reliability for the transport processes to one actor, such as EXW (customer reliable for the transport) or DDP (supplier reliable for the transport) increases the predictability and the planning basis for the integration into SC concepts. However, depending on the SC structure and transport distance a CT concept can also be integrated for the pre- or ongoing haulage for the other incoterms with shared reliabilities, such as FOB (free on board; delivery to an agreed port) or DAF (delivered at frontier; delivery to an agreed delivery point on a frontier).

Table 3 - 10 summarises the findings on the impact of procurement concept configurations on SCP requirements developed in section 3.2. The product type is excluded in this illustration since it is assumed in a SC concept.

²⁰⁰ cf. ICC (2010a); Gabler (2011); ICC (2010a).

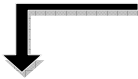
reading direction  SCP requirements	impact of procurement concept configuration				
		supplier choice	procurement area	procurement time	incoterms
time	delivery window	X	X	X	
	transport time	X		X	
	delivery frequency	X		X	
space	transport distance	X	X		
	distance to infrastructure	X			
	number of sources and destinations	X			
shipment size and transport quantity		X		X	
cost	transport cost/ turn-over	X	X	X	X
flexibility	time	X	X	X	X
	quantity	X		X	
	space	X	X		
reliability	adherence to schedules	X	X	X	
	quality	X	X	X	X

Table 3 - 10: Impact of procurement concept configuration on SCP requirements.

Next to the procurement concept, the production and distribution concepts have specific SCP requirements regarding transport concepts. The following section discusses the meaning of the production concept on the integration of CT.

3.3.3 Impact of Production Concept Configuration on Transport Concepts

This section clarifies the elements and processes of the production concept to identify adaptation points for the performance-oriented integration of CT into SC concepts. In a first step, the meaning of the production concept for SCP is worked out. In a second step, the structures and processes of production concepts are described. Furthermore, the impact of the SC strategy on production concept configuration is discussed. Finally, classification criteria for production concepts are identified and the SCP requirements regarding the embedded and linking transport concepts are worked out.

3.3.3.1 Meaning of the Production Concept for SCP

According to Wildemann (2004), modern production concepts can be characterised by the orientation towards the main objectives of the company and the SC. The segmentation of production and network organisation are the central ways to deal with the increasing complexity of products and production systems.²⁰¹ A production concept encompasses the definition of all planning, control, implementation and monitoring processes for the production and assembly as well as the determination of the corresponding structures, resources and management processes.²⁰²

Transport concepts are central to the operation of the production concept. They link the production concept with the upstream processes of the procurement concept and with the downstream processes of the distribution concept. Furthermore, the internal transport of raw materials, parts and modules to specific facilities and to buffer and warehouses is accomplished. These tasks can be defined as production logistics in a narrower (internal processes) and wider sense (external processes).²⁰³

The following section introduces the basic processes, elements and objectives of production concepts to understand how it influences SCP as well as the configuration of transport concepts.

3.3.3.2 Structures and Processes of Production Concepts

Production can be defined as the manufacturing and altering of goods and services by the aid of other goods and services.²⁰⁴ Thus, the production concept must meet the SCP requirements resulting from a changing market environment. A high adaptation speed to the environment is necessary to reach a high level of market and customer orientation.²⁰⁵ Hence, a production concept's target system focuses on the optimal use of resources with regard to the triad of costs, quality and time completed by the objective of flexibility. In brief, the general target of a production concept is to increase productivity, decrease lead and production times, reduce production costs (material cost, personnel, facility cost, etc.) and improve product quality.²⁰⁶

²⁰¹ cf. ICC (2010b), p. 1.

²⁰² Definition developed on the basis of Wildemann (2004.), pp. 295.

²⁰³ cf. Ibid., pp. 295.

²⁰⁴ cf. Arnold et al. (2008); Kern (1979), p. 5;

²⁰⁵ cf. Wildemann (2004a), p. 1.

²⁰⁶ cf. Ibid., p. 295.

The production process can be distinguished according into (1) PPC processes, (2) the internal transport of materials and work pieces (between different production steps), (3) the part/components or system manufacturing and (4) the component/system pre- and end assembly.²⁰⁷

PPC is a central element of the production concept. The optimal supply of production with resources according to time, quality and flexibility aspects is the main target of PPC. Usually, powerful software applications support PPC (so-called ‘PPC systems’).²⁰⁸

The specific configuration of the production concept is significantly influenced by product type, market demand and SC strategy. The following section clarifies the relationship between SC strategy and production concept configuration.

3.3.3.3 Classification and Configuration of Production Concepts – Identification of Design Variables relevant for CT Integration

This section introduces different classification criteria for production concepts. The criteria that influence the SCP requirements regarding transport concepts are identified and discussed.

Sames and Büdenbender (1997) proposed a morphological scheme to describe different order fulfilment strategies in production concepts.²⁰⁹ Usually, the morphological scheme is applied to a first analysis and documentation of a given production concept as well as for the description of a prospective future state. It is restricted to the manufacturing of piece goods.²¹⁰ The authors distinguished between classification criteria regarding the initialisation of order fulfilment activities (e.g., order release), product characteristics (e.g., product portfolio, product structure, product design), disposition characteristics (e.g., release of secondary order demand, stocking type) and manufacturing process characteristics (e.g., production control logic).

Several of these classification criteria depend on product type, market demand or SC strategy and are thus, not considered as design variables for the performance-oriented integration of CT into SC concepts.

²⁰⁷ cf. Arnold et al. (2008), pp. 27.

²⁰⁸ cf. Hackstein (1989), p. 262; Luczak et al. (1999), pp. 250; Wiendahl (2009), p. 1.

²⁰⁹ cf. Wiendahl (2009).

²¹⁰ In contrast to process manufacturing. cf. Sames et al. (1997), p. 77. For further considerations, process manufacturing is excluded.

Additionally, it is assumed that production type²¹¹ and assembly type are not alterable, but mainly depend on product type and market demand for the purpose of CT integration.²¹² Table 3 - 11 shows the classification criteria for production concepts that influence the transport concept configuration.

classification criteria	characteristics			
order release	production on demand (single orders)	production on demand (frame orders)	customer anonymous pre-production	production on stock
secondary demand release	order oriented		partly order oriented, partly period-oriented	period-oriented
stocking type	no stocking of demanded goods	stocking of demands on low structure levels	stocking of demands on high structure levels	stocking of goods
production control logic	pull-control logic		push control logic	

Table 3 - 11: Classification criteria for production concepts with regard to the impact on transport concepts.²¹³

Order Release

'Order release' characterises the linking of the production and sales market. The central dimension for differentiation is the release type of primary demand. This release can be initiated by customer orders (production on demand with single orders or framework orders), by sales expectations (production on stock) or by a combination of these two basic order release types. In the case of a combination, certain product components are pre-manufactured based on sales expectations, which are then completed or end assembled after customer orders occur.²¹⁴ Thus, the order release type influences time-related performance requirements as well as time-related flexibility aspects. Furthermore, the type of order release influences the shipment size and transport quantities as well as the requirements regarding the corresponding flexibility.

Transferring these considerations to CT integration implies that because of the high production quantities, stable production and resulting long lead times a good planning basis positively influences the applicability of CT into a SC concept.

²¹¹ The 'production type' characterizes the frequency of the repetition of production processes. cf. Luczak et al. (1999).

²¹² The 'sourcing type' determines the ratio of internal and external sources goods. The higher the number of outsourced production processes the higher the number, quantity and frequency of transport processes into the focal company location. cf. Sames et al. (1997); Luczak et al. (1999). The sourcing type is excluded from considerations here, since the field of procurement and sourcing comprehensively discusses the impact of procurement concept configuration on transport concepts (cf. section 3.2.2).

²¹³ own illustration in accordance to Arnold et al. (2008); Kern (1979); Luczak et al. (1999), p. 110; Sames et al. (1997), pp. 301.

²¹⁴ cf. Arnold et al. (2008); Kern (1979); Luczak et al. (1999), p. 110, Sames et al. (1997), pp. 301.

Release of Secondary Demand

The dimension of the *'release of secondary demand'* is tightly connected with the demand determination of products and components. The dimension describes the connection to the procurement concept. The procurement concept must ensure the production concept's material demand. Thus, the more regularly the demand for the products can be determined with regard to time and quantity, the more regularly the secondary demand can be specified. The secondary demand determination can be order-oriented, period-oriented or a combination of both. Period-oriented demand determination means the secondary demand is gathered and determined for several orders for a defined time period. The combined and the period-oriented demand determination is especially applied in companies with a wide spectrum of product variants. Standard components in several orders can be gathered and commonly sourced. The applied transport concepts are influenced not only by the production quantities, but also by the available advance time to set up the necessary transport processes.²¹⁵ The release of secondary demand influences time-related SCP requirements as well as the required time flexibility. Owing to the impact of secondary order release on inventories, it influences capital commitment and warehouse costs.

The higher the share of period-oriented secondary order release the better the applicability of CT concepts. Owing to the periodic character, the required predictability for the integration of CT concepts is assumed. However, further situation-specific characteristics must be included in the consideration, especially transport planning for the delivery of orders. The character of the transport concept (periodic- or demand-oriented) can differ from the release of the secondary demand.

Stocking Type

'Stocking type' describes the scope of stocked parts, assembly groups and goods. For the production of customer-specific goods, for instance in special engineering or plant manufacturing, stocking is usually not possible. In SCs with a focus on short delivery times,²¹⁶ delivery times are often shorter than in a manufacturing process. Thus, there must be stocks for a customer anonymous pre-manufacturing of standard

²¹⁵ In the original scheme, two dimensions – the determination of product/component demand and the determination of secondary demand – are distinguished. The content is here summarised for the focus on transport and logistics processes. The way and the structural level of demand determination are used to distinguish five types of demand determination.

²¹⁶ cf. section 3.1.3: lean II - continuous replenishment or agile SCs.

components. This stocking can be restricted to single demand positions, such as parts and assembly groups or can encompass readily manufactured and assembled products.²¹⁷ The stocking type influences the requirements regarding transport time and delivery frequency. The lower the stock levels the higher the shorter transport times and delivery frequency and the smaller the shipment size as well as the corresponding flexibility aspects. Furthermore, there are requirements on reliability regarding adherence to schedules as well as product quality.

It can be summarised that stocking goods generally supports the integration of CT concepts. If goods are stocked, lead times are comparably long, bundling effects can be realised and thus, transport quantities are presumably high.

PPC Logics

There are two basic '*PPC logics*'. In a so-called push system, the work is scheduled and order releases are based on demand. In a pull system, the work is authorised and order releases are based on the system's status.²¹⁸

Push systems are inherently due date-driven. Products are 'pushed' into production and are taken to the next work centre on schedule. 'Push' thereby releases materials into production as customers' orders are processed and the materials become available. The system has centralised planning and there is aligned information and material flows only between the predecessor and successor working centres. Material Requirement Planning or Manufacturing Resource Planning (MRP), Optimised Production Technology (OPT) and order release with load limitation are typical 'push' systems.²¹⁹

Pull systems are inherently rate-driven. Products are pulled through production. Thus, it is a control measure to release materials into production only when they are needed. Typical 'pull' systems' control strategies are ConWiP (Constant Work in Progress)²²⁰ and Kanban.²²¹ This pull principle is also used to coordinate supply relationships, such as the synchronised supply concepts of JIT and JIS.

²¹⁷ Common for simple standard products, which are customer anonymously sold.

²¹⁸ For the planning and control of production orders several more approaches and methods have been developed. For an comprehensive overview see for instance Sames et al. (1997). Some of them were implemented in commercial PPC-systems, but in practice simple methods like forward and backward scheduling as well as priority rules are commonly applied. cf. Teunis (2003), p. 33.

²¹⁹ cf. Teunis (2003); p. 335; Wiendahl (2009), p. 65.

²²⁰ cf. Luczak et al. (1999) The strategy of ConWiP stabilises the inventory in a production system. The inventory is measured either by the number of parts or by the number of orders in the system. As soon as the inventory in a production system has reached the target inventory a new order is only 'pushed' into the system every time another order leaves it.

²²¹ cf. Lödging (2001), pp. 95, pp. 66; Luczak et al. (1999); pp. 342.

Relevant for the configuration of transport concepts are especially the impact of the PPC logic on the inventories, transport quantities, transport times as well as pickup and delivery times and the definition of the specific adherence to schedules. In production systems with a push control logic, transport concepts must be adapted to the hazard of huge stockings caused by planning defects. In a pull controlled production system, the immediate processing of orders requires low inventory levels, which require a high adherence to schedules and quality in transport processes. The production control logic especially influences the requirements on delivery windows. Furthermore, shipment size as well as flexibility and reliability are influenced.

The availability of high transport volumes and a high level of predictability support the applicability of CT into a SC concept. In a push system, the level of predictability is comparably higher than it is in a pull system. However, for the configuration of a transport concept the type of product (or variant) is not necessarily important. The predictability of transport quantity and transport time is of central interest. Thus, the applicability of CT cannot be evaluated separately based on the PPC logic, but the entire SC concept configuration must be considered.

Table 3 - 12 summarises the findings on the impact of production concept configurations on SCP requirements developed in section 3.2.

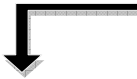
reading direction  SCP requirements	impact of production concept configuration				
		order release	release of secondary demand	stocking type	production control logic
time	delivery window	X	X		X
	transport time	X	X	X	
	frequency	X	X	X	
space	transport distance				
	distance to infrastructure				
	no. of sources and destinations				
shipment size and transport quantity		X		X	X
cost	transport cost/ turnover		X		
flexibility	time	X	X	X	X
	quantity	X	X	X	X
	space				
reliability	adherence to schedules			X	X
	quality			X	X

Table 3 - 12: Impact of production concept configuration on SCP requirements.

After the discussion of the different configuration elements to influence the SCP requirement on transport concepts, the meaning of the production concept configuration on the integration of CT is discussed.

3.3.4 Impact of Distribution Concepts on the Configuration of Transport Concepts

This section clarifies the elements and processes of distribution concepts to identify adaptation points for the performance-oriented integration of CT into SCs. In a first step, the meaning of the distribution concept for SCP is worked out. In a second step, the structures and processes of the distribution concept are described. Furthermore, the impact of the SC strategy on the design of the distribution concept is discussed. Finally, classification criteria for distribution concepts are discussed and criteria influencing the SCP requirements regarding the embedded and linking transport concepts are identified.

3.3.4.1 Meaning of the Distribution Concept for SCP

The distribution concept encompasses the definition of the planning, control, implementation and monitoring of all distribution processes as well as the determination of the corresponding structures, resources and management processes. Distribution means the efficient physical delivery of goods from the manufacturer to the customer.²²² The distribution concept links the supplier and the buyer. Thus, distribution planning focuses on customer services and distribution costs.

Distribution can be defined as the allocation of products from the manufacturer to the end customer.²²³ In particular, the distance between manufacturer and sales markets, fluctuations in demand, the balancing of production lot sizes, transport units and sales units as well as the assortment for the end customer or retail are influencing factors. The term ‘distribution logistics’ has an even wider scope; it encompasses the planning and control distribution nets.²²⁴ The general target of distribution concepts is to increase customer service and to decrease distribution costs (transport, packaging,

²²² cf. Wiendahl (2009), p. 9.

²²³ cf. Pfohl (2010), p. 198.

²²⁴ cf. Wahl (1999), p. 9.

stocking, personnel, rent, etc.).

Nowadays, sales markets and production locations are often geographically remote from each other. Huge distances have to be covered to deliver the product to the end customer. Furthermore, companies classify the sales market according to customer groups or sales regions, which resemble their market-specific characteristics, such as frequency, quantity and type of demanded goods. To meet the demand of all sub-markets often companies set up complex distribution systems with decentralised, multi-level stocks. Thus, central problems are the choice of the optimal structure of the distribution net, the design of I&C systems and technical systems of information and material flow processes.²²⁵

The distribution concept must be carefully adjusted and linked with production as well as with the embedded and linking transport concepts. The distribution concept is central for each SC concept since it ensures the provision of goods for the end customer and thus, ensures financial flow.

Transport and logistics processes ensure the material flow of distribution concepts. Transportation processes accomplish the spatial balancing task and logistics processes, such as stocking and transshipment, and balance demand fluctuations and viable lot sizes of production.

In the following section, the basic processes, elements and objectives of distribution concepts are introduced to understand how the distribution concept configuration influences SCP as well as the design and configuration of the embedded and linking transport concepts. The discussion of the requirements on the distribution concept's requirements on transport concepts is central to gain further insights into the performance-oriented integration of CT into SC concepts.

3.3.4.2 Structures and Processes of Distribution Concepts

The distribution concept is the SC's interface with the (end) customer. Thus, it has to reflect the end customers' requirements in terms of SCP. SCP-oriented key figures become transparent to the end customer through distribution. As a result, the end customer has to be integrated into SC concepts. Central standardised concepts for this

²²⁵ cf. *Ibid.*, p. 9.

integration include CRM²²⁶ and ECR.²²⁷

Distribution concepts bridge the spatial and temporal distances between the production and consumption of goods by means of logistics and transport processes.²²⁸ According to Siller (2011), the main tasks of distribution logistics are demand forecasting, inventory planning, inventory usage, warehouse filling, order processing as well as physical delivery.²²⁹ The three basic elements of a distribution system at the material flow level are warehouses, transport and inventories (warehouse stock and transport stock). The distribution concepts encompasses five main processes to ensure products are delivered from manufacturer to customer: (1) planning and construction of warehouse locations,²³⁰ (2) warehousing, (3) packaging, (4) transport and (5) administrative processes, such as order processing, invoice processing and sales processes.²³¹ Often, these tasks are also defined as '*distribution logistics*' in the literature.²³²

Distribution Structures

To understand the specific challenges of CT integration from the perspective of the distribution concept, a general understanding of the structure of distribution concepts is necessary. For systematic consideration, the structures of distribution systems can be affiliated to four basic structures. Pfohl (2010) distinguished three basic types of material flow: direct, indirect and combined material flow (Figure 3 - 6).²³³

A distribution structure with direct material flow from the manufacturer to the customer is called a one-level system. One-level systems allow the delivery without additional stocking and/or handling processes. In practice, small companies in the capital goods industry or companies with few, huge customers have one-level distribution structures.²³⁴ Often, 3PLs are responsible for the distribution of goods or operation of DCs.

If the geographical distance between source and delivery points is too long to ensure the defined delivery time, the setup of multi-level distribution systems is necessary.

²²⁶ For details on the concept of CRM see Ibid., p. 391; Choy et al. (2002), p. 387.

²²⁷ For details on the concept of ECR see Sennheiser et al. (2008), Siebel (2002), p. 391.

²²⁸ cf. Sennheiser et al. (2008), p. 9.

²²⁹ cf. Wahl (1999), p. 9.

²³⁰ There is a number of publications on quantitative location planning. See for instance Siller (2011), p. 17.

²³¹ cf. Pfohl (2010), pp. 198.

²³² See Wahl (1999).

²³³ cf. Siller (2011), p. 6.

²³⁴ cf. Pfohl (2010), p. 10.

According to Pfohl (2010), these multi-level concepts are characterised by indirect material flows.²³⁵ The material flow is disrupted by at least one additional distribution site. The activity of such a disruption point can be either bundling (concentration / bundling point)²³⁶ or allocating goods (distribution point).²³⁷

Additional storage sites are implemented to supply sub-markets, in which a high service level is a competitive factor. By establishing geographical proximity between DCs and customer sites huge distances and average delivery times can be reduced. Furthermore, there are legal restrictions, such as night and weekend driving bans that require the introduction of additional storage and distribution levels.²³⁸

To determine the location of the distribution and storage points of specific goods, demand regularity and customer preferences are central. According to the idea of an ABC analysis, products with a high inventory-to-sales ratio should be made available to the customer. Products with lower demand should be stocked at a higher distribution level in order to decrease so-called edge assortment problems ('selective storage').²³⁹

A combined material flow features both direct and indirect material flows. Through the combination, key accounts can be supplied directly to ensure a high service level, while small customers can be supplied via multi-levels to utilise transport capacities sufficiently.²⁴⁰

²³⁵ cf. Wahl (1999), p. 201.

²³⁶ Delivery of small lot sizes from different production sites, gathering at the concentration point and transshipments on a new transport vehicle, for instance a vessel or wagon.

²³⁷ For instance a central warehouse that receives products from a single production site, buffers these and supplies downstream distribution warehouses.

²³⁸ cf. Pfohl (2010), p. 202.

²³⁹ cf. Ibid., p. 11.

²⁴⁰ cf. Ibid., p. 203.

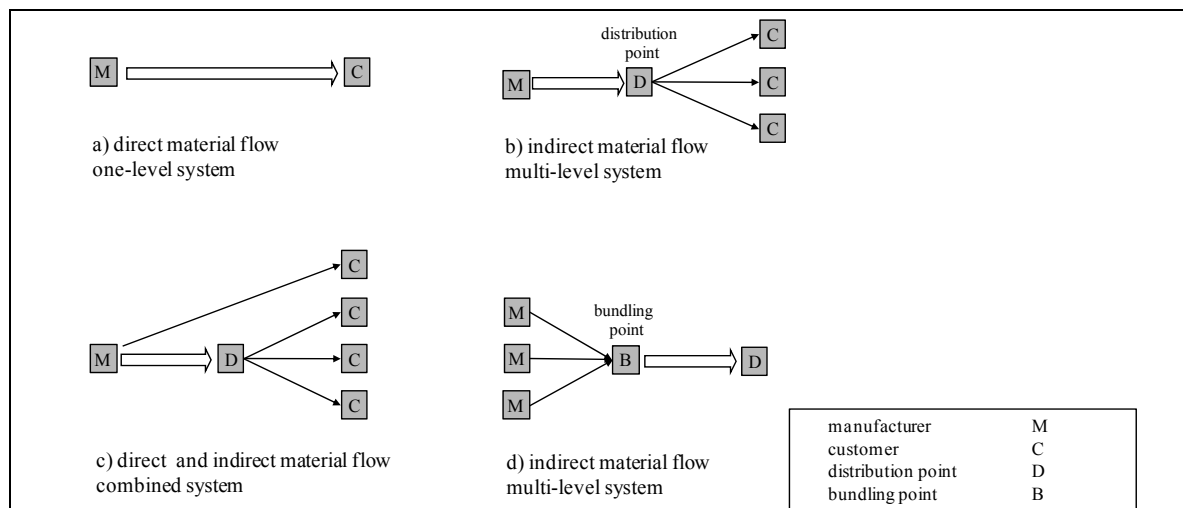


Figure 3 - 6: Basic structures of distribution systems.²⁴¹

The structure of a distribution concept can be visualised by a multi-level net of knots and edges. This structure can also be called '*distribution net*'.²⁴² According to Fleischmann (1993), a distribution net can be defined as the flow of end products from the production site to the customer.²⁴³ This flow consists of transport, storage and handling processes. The net consists of production sites, centralised warehouses, regional warehouses, DCs, transshipment points and customers.

Often, different distribution channels are chosen for different types of customers.²⁴⁴ Direct deliveries of key accounts from centralised warehouses and production sites are common, since these customers offer sufficient transport quantities. Smaller customers are served by DCs.²⁴⁵

There are two central criteria to distinguish between different distribution networks. A vertical distribution structure means a distribution network structure from production sites and suppliers to centralised warehouses and distribution sites to the customers. A horizontal distribution structure means the number of warehouse sites per storage level.²⁴⁶

Common weak points are historically grown distribution structures leading to high inventory and transport costs. The low level of the process integration of logistics service providers leads to high inventory levels that could be reduced by higher in-

²⁴¹ cf. Wahl (1999), p. 11.

²⁴² cf. Ibid., p. 11.

²⁴³ cf. Fleischmann (1993); Wahl (1999), p. 12.

²⁴⁴ cf. for instance Changxian et al. (2009); Frazier (1999); Hua et al. (2011); Parment (2008); Zimmermann et al. (2009).

²⁴⁵ cf. Siller (2011), pp. 18; Wahl (1999), pp. 10.

²⁴⁶ cf. Wahl (1999), p. 11.

formation availability. Still, the differentiation of logistics services, especially for e-business business-to-customer, is not sophisticated.²⁴⁷ At the I&C level, the virtualisation of inventories and the implementation of fleet management systems as well as customer information systems can send a delivery note by email.²⁴⁸

The specific configuration of the distribution concept is significantly influenced by product type, market demand and SC strategy. The following section clarifies the relationship between SC strategy and distribution concept configuration.

3.3.4.3 Classification and Configuration of Distribution Concepts – Identification of Design Variables relevant for CT Integration

This section introduces different classification criteria for distribution concepts. The section identifies the criteria that influence the SCP requirements regarding transport concepts.

Hoppe (2002) proposed a classification for different distribution concepts. The author suggested customer structure, assortment width, shelf life and typical products as classification criteria.²⁴⁹ However, for the thesis in hand it is assumed that product- and demand-related criteria cannot be adapted to influence the integration of a CT concept. Furthermore, Hoppe (2002) presented four classification criteria that influence the SCP requirements of transport concepts: (1) regional structure, (2) echelon structure, (3) delivery service and (4) delivery time point. Table 3 - 13 gives an overview of the transport-relevant configuration criteria for distribution concepts.

classification criteria	characteristics					
regional structure	several DCs per country		one DC per country		several countries per DC	one central DC
echelon structure	direct material flow; one level		indirect material flow, multi level		combined – direct and indirect	indirect material flow, multi-level
delivery service	'same day'	'next day' or 'next morning'	24 - 48 hours		24 - 72 hours	> 72 h
delivery time point	determined		flexible		windows	free

Table 3 - 13: Classification criteria for distribution concepts with regard to the impact on transport concepts.²⁵⁰

²⁴⁷ cf. Siller (2011), pp. 18.

²⁴⁸ cf. Banerjee et al. (2007); Bose et al. (2008); Fabbe-Costes et al. (2008); Ursel et al. (2010).

²⁴⁹ cf. Hoppe et al. (2002), pp. 24.

²⁵⁰ cf. illustration with significant adaptations in accordance to Ibid., pp. 24.

Regional Structure

The classification is oriented to the *regional structure* of the distribution concept, which can be of decentralised, national, regional and central character.²⁵¹ This classification corresponds to the availability of more or less DCs in the distribution network or in a sales region. Regional structure influences transport time and delivery frequency. Based on this, the shipment size is influenced. In particular, spatial aspects, such as transport distance, distance to infrastructure connection and number of sources and destinations as well as flexibility aspects, are influenced by the regional structure of a distribution concept. As a result, the regional structure influences the cost dimension, too.

In general, the centralisation of goods, and thereby a regional structure with only one or a few DCs per country, supports the integration of CT concepts. It can be assumed that the greater the number of DCs the more transport quantities are split up. However, the specific SC concept configuration must be considered for a comprehensive evaluation of CT applicability.

Echelon Structure

The *echelon structure* corresponds to the distribution structure introduced in section 3.3.4.2. This characterises the number of distribution levels and explains whether the material flow in the distribution concept is direct, indirect or a combination of both (Figure 3 - 6).

The echelon structure gives information about the structure of material flows in the distribution network. In general, the fewer distribution sites in the network there are the higher are the bundling potential and transport volumes and thus, the better the CT applicability. However, as for the evaluation of the regional structure the specific SC concept configuration, transport quantities, relations and times have to be considered. The echelon influences transport time, delivery frequency and thus, shipment size as well as corresponding flexibility. Furthermore, the echelon structure affects spatial dimension, namely transport distance, distance to infrastructure connections and number of sites. Thus, the echelon structure also influences cost.

²⁵¹ cf. Ibid., pp. 13, 24.

Delivery Service

The *delivery service* determines how far in advance the order for a specific delivery needs to be placed. For instance, in the medical and pharmacy industry, ‘same day’ delivery is common. ‘Next day’ and ‘next morning’ deliveries are usual in retail as well as for spare parts. Delivery times of one or more days, weeks or months are possible depending on the types of goods, the SC strategy and regional structure.²⁵² The delivery service especially influences transport time and delivery frequency as well as the corresponding flexibility and adherence to schedules. Thus, delivery time also affects costs.

As shown in section 2.3.8, long lead times support the integration of CT into SC concepts. Thus, in general, a longer delivery time positively influences the applicability of CT. However, depending on the SC concept configuration predictability of the transport processes an integration of CT for lead times longer than one day is possible. For same-day delivery, the applicability is restricted to special framework conditions (e.g., proximity of infrastructure connection, appropriate train departure).

Delivery Time Point

The *delivery time point* determines whether the delivery has to arrive at the destination at a determined (often on a schedule basis), at a flexible (with prior advice) or at a free time point. In practice, time window concepts are increasingly applied.²⁵³ The impact of the delivery time point type is restricted to temporal SCP aspects, namely it affects delivery window, transport time and delivery frequency.²⁵⁴

In general, a free delivery time point eases the integration of CT concepts into a SC concept. However, depending on the situation-specific CT concept configuration it is possible to meet defined delivery times and delivery windows.

Table 3 - 14 summarises the findings on the impact of distribution concept configurations on SCP requirements developed in section 3.2.

²⁵² cf. Changxian et al. (2009); Michaelraj et al. (2009); Siller (2011).

²⁵³ cf. Campbell et al. (2004); Quak et al. (2009); Zobel (2011).

²⁵⁴ cf. Hoppe et al. (2002), pp. 24.

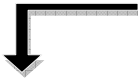
reading direction  SCP requirements		impact of distribution concept configuration			
		regional structure	echelon structure	delivery service	delivery time point
time	delivery window				X
	transport time	X	X	X	X
	delivery frequency	X	X	X	X
space	transport distance	X	X		
	distance to infrastructure connection	X	X		
	number of sources and destinations	X	X		
shipment size and transport quantity		X	X		
cost	transport cost/turnover	X	X	X	
flexibility	time	X	X	X	
	quantity	X	X	X	
	space	X			
reliability	adherence to schedules			X	
	quality				

Table 3 - 14: Impact of distribution concept configuration on SCP requirements.

After the discussion of the different configuration elements that influence the SCP requirements regarding transport concepts, the meaning of the distribution concept configuration on the integration of CT concepts is finally discussed.

3.4 Development of a CT Concept Typology - Classification using SCP Profiles

This section introduces a classification approach for CT concepts focusing on material and information flows. Three different CT concept types are characterised by so-called 'performance profiles'. These profiles can be understood as the equivalent of the SCP performance profiles that express the SCP requirements of a certain SC concept configuration.

The CT business model classification introduced in section 2.2.2.2 serves as the basis, but the typology does not aim to cluster similar business models, but rather group similar SCP requirements regarding CT transport. Therefore, the typology of CT concepts follows the classification approach of SCP requirements (as developed in section 3.2), but focuses on the description of performance capabilities rather than performance requirements.

Different CT concepts are classified according to spatial and time-related transport

performance characteristics. This means that the concept is viewed from a SC perspective.²⁵⁵ Furthermore, the performance characteristics are discussed based on the performance categories introduced in section 3.2. There are three different types of CT concepts focusing on the material and information flows: (1) *line transport with regular booking*, (2) *line transport with flexible booking* and (3) *packaged goods networks*.

There is no discussion on product type, reliability and costs. The performance characteristics in these categories must be determined situation specifically. Hereby, the three identified CT types do not significantly differ regarding these dimensions. However, in practice the usage of these dimensions supports the specification of the CT performance profile.

Line Transport – Regular Booking

The '*line transport - regular booking*' is a service for shippers that regularly book a certain transport on a regular train line.

This CT concept type is characterised by its comparably high speed (short transport time), punctuality and frequency. Owing to the comparably short transport times and high frequency, the CT concept can be applied to comparably short transport distances (cf. chapter 5). Because of the high transport frequency, the concept is suitable for comparably short distances from shipper and consignee to the infrastructure connection. Usually a line transport concept connects only a few sources and destinations (cf. section 3.2.1 relation transport). Mass goods or FTL are suitable for the application of line transport with regular bookings. Although the time flexibility regarding certain connections is low (train departures are usually not delayed if a certain shipment is missing), shippers have high flexibility regarding switching transport quantities to the next train or the next day. This flexibility regarding transport quantities and space is high, too. Table 3 - 1 summarises these findings.

The dark grey fields characterize the highest performance level that can be reached by the specific CT concept. Grey fields show lower performance levels that can obviously be met, too. White fields characterise that a CT concept can only restrictedly reach this performance level. A cross means that the CT is not suitable for this per-

²⁵⁵ The classification of CT services introduced in section 2.2.2.2 takes a CT service provider's point of view and aims at the determination of the underlying business model.

formance requirement.

dimension	performance criteria	characteristics				
time	delivery window	5 min	30 min	1 h	6 h	day
	transport time	< day	24 h	48 - 72 h	> 72 h	
	delivery frequency	multiple per day	1 x day	1 x week	sporadic	
space	transport distance	short	medium	high		
	distance to infrastructure connection	low	medium	high		
	number of sources and destinations	1 - 1	n - 1/1 - n	few - n / n - few	n - m	
quantity	shipment size / transport quantity	> mass good	> FTL	LTL	packaged	
flexibility	time	high	medium	low		
	quantity	high	medium	low		
	space	high	medium	low		

Table 3 - 15: Characteristics of the CT concept 'line transport - regular booking'.
 (dark grey = suitable (highest performance level); grey = suitable (lower performance level);
 white = restrictedly suitable; X = not suitable)

For instance, *Swiss Post* provides a CT service up to eight times a day. This allows shippers to cancel advised transport in the short-term (e.g., because of congestion) and offers the ability to switch to the next train (usually 2–3 h later) without additional cost.²⁵⁶

Another example is *ERS Railways* (a subsidiary of *A.P. Möller*), which offers regular shuttle trains for seaport transport.²⁵⁷ The *Hamburger Hafen und Logistik AG (HHLA)* offers shuttle trains between the Hamburg ports and the terminals in Prague. *ERS* and the *HHLA* offer the booking of transport capacities on a regular basis, for instance daily, weekly or monthly.²⁵⁸

Line Transport – Flexible Booking

The CT concept of '*line transport - flexible booking*' is similar to the previous concept in terms of service production. The concept aims at a high level of flexibility level for the shipper. This means a shipper can flexibly and in the short-term book transport or can switch shipments on regularly offered lines without pre-booking, but there is no guarantee of free capacity. This type of CT is applicable for shippers for spontaneous congestion, weather changes and strongly varying transport volumes.²⁵⁹

CT actors have a high risk to fill their capacities, but they are able to increase price levels for the sporadic service. However, in combination with a dynamic pricing

²⁵⁶ For further details to the CT offer of the *Swiss Post*, see chapter 5.

²⁵⁷ cf. ERSRail (2011).

²⁵⁸ cf. Parment (2008), p. 33.

²⁵⁹ For instance, for the hinterland transport of globally sourced goods arriving in a sea port.

model the shipper can save money by early booking, whereas the CT operator gets a higher predictability of demand.

The time-related performance of a line transport with flexible booking is comparably high regarding the time window of delivery. Owing to the high punctuality, even short delivery windows can be met. The transport time is longer in comparison with the regular booking since the availability of transport capacities at the desired time point cannot be guaranteed. Because of the sporadic character of the demand, this transport concept is especially suitable for long distance transport and when infrastructure connections are comparably close. As in the previous concept, the line transport concept usually connects few sources and destinations. Owing to its sporadic character, it is suitable for FTL. The flexibility of the line transport with regard to booking is comparably high in terms of time, quantity and space. However, it must be considered that the shorter the time between booking and departure, the higher the risk that there is no sufficient capacity on the desired transport. Table 3 - 2 summarises these findings.

dimension	performance criteria	characteristics				
time	delivery window	5 min	30 min	1 h	6 h	day
	transport time	< day	24 h	48 - 72 h	> 72 h	
	delivery frequency	multiply per day	1 x day	1 x week		sporadic
	transport distance	short	medium	high		
space	distance to infrastructure connection	low	medium	high		
	number of sources and destinations	1 - 1	n - 1/1 - n	few - n / n - few	n - m	
quantity	shipment size / transport quantity	> mass good	> FTL	LTL	packaged	
flexibility	time	high	medium		low	
	quantity	high	medium		low	
	space	high	medium		low	

Table 3 - 16: Characteristics of the CT concept 'sporadic usage of line relation'.
 (dark grey = suitable (highest performance level); grey = suitable (lower performance level);
 white = restrictedly suitable; X = not suitable)

Packaged Goods Network

The CT concept of '*packaged goods network*' focuses on the transport of packaged goods and LTL. In the past, there have been several attempts to realise packaged

good networks via CT, e.g., the Swiss *Cargo Domino*²⁶⁰ and *DHL Parcel Intercity (PIC)*²⁶¹ and the express cargo trains operated by *Hellmann Rail Solutions*.²⁶²

The lead time is comparably long to realise the different bundling and recombination processes. Usually a maximum lead time is offered. Thus, the delivery window for delivery and pickup is comparably long. The distance to the next terminal can be rather long, since usually there is a number of pickup sites and pre-haulage shipments are bundled. Thus, the packaged goods network is sensible for operation with multiple shippers as well as many loading and unloading sites. The flexibility of the concept is comparably high. The time, quantity and pickup and delivery places for shipments can be changed at short notice. Table 3 - 3 summarises these findings.

dimension	performance criteria	characteristics				
time	delivery window	5 min	30 min	1h	6 h	day
	transport time	< day	24 h	48 - 72 h	> 72 h	
	frequency	multiply per day	1 x day	1 x week		sporadic
space	transport distance	short		medium		high
	distance to infrastructure connection	low		medium		high
	no. of sources and destinations	1 - 1	n - 1/1 - n	few - n / n - few	n - m	
quantity	shipment size / transport quantity	> mass good	> FTL	LTL	packaged	
flexibility	time (variance of lead time/ rate)	high	medium		low	
	quantity (variance / rate)	high	medium		low	
	space (variance / rate)	high	medium		low	

Table 3 - 17: Characteristics of the CT concept 'network relation'.
 (dark grey = suitable (highest performance level); grey = suitable (lower performance level); white = restrictedly suitable; X = not suitable)

After the discussion of different CT concept types and performance profiles, the following section summarises the main results of chapter 3.

3.5 Intermediate Findings

Chapter 3 addresses the meaning of CT as an element of SC concepts. The section introduces the SC sub-concepts, namely the procurement, production and distribution

²⁶⁰ cf. SBBCargo (2011).

²⁶¹ Operated by *Railion* later *DB Schenker Rail*. cf. Heinrici (2011). A CT train between Hamburg and Munich operated by *DHL* introduced in 2001. Concentrated on the night jump and with more than 140 km/h and up to 99% punctuality. cf. Ernst (2011).

²⁶² Initiated 2004 between Hannover and Nuremberg. Recently eight railway stations (North: Hamburg, Bremen, Osnabrück, Hannover) and (South: Frankfurt, Nuremberg, Regensburg, Landshut, Basel). cf. Homeyer (2004), p. 14.

concepts based on the relationship with a specific SC strategy. Cause-and-effect relationships between the elements of the SC and CT concepts are worked out based on an empirically developed classification of SCP requirements. Therefore, chapter 3 answers the first sub-ordinated research question and contributes to answering the second.

Chapter 3 introduces the SC concepts as the operationalisation of SC strategies. A SC strategy depends on the product type as well as supply and demand-related characteristics. This means the SC strategy influences the configuration of the procurement, production and distribution as well as the embedded and linking transport concepts. The SCP requirements regarding transport concepts of specific sub-concept, namely the procurement, production and distribution concepts, are discussed. The SCP requirements can be summarised in a so-called '*SCP requirements profile*'. This is the basis for the identification of adaptation points for the integration of CT into a specific SC concept. Similarly, each CT concept be characterised by a so-called '*performance profile*'. These profiles are the focus of the service characteristics, rather than of service production.

The presented approach for the description of SC concepts and their requirements on transport concepts is universal. It is neither restricted to a specific type of transport concept nor to a specific type of SC concept. Moreover, the SCP requirements of standardised SC concepts can be described by the presented classification approach.

Table 3 - 18 briefly characterises the different CT types regarding suitable application fields.

	CT concept types	characteristics
A	line transport - regular booking	high transport quantities (mass good and FTL), short lead times, high frequencies and low variations, high level of predictability
B	line transport - flexible booking	high level of flexibility, comparably high level of adherence to schedules, medium lead time, comparably high costs
C	CT network	small transport volumes (packaged good) and packaged goods, long lead time, many locations, high costs

Table 3 - 18: Overview on CT concept and suitable application fields.

Table 3 - 19 applies the developed structuring approach and states the performance profiles of the three different CT concept types.

	CT concept type	A	B	C
time	delivery window	high	medium	low
	transport time	high	high	low
	delivery frequency	high	low	medium
space	transport distance	short	short	medium
	distance to infrastructure connection	short	short	medium
	no. of sources and destinations	few-few	few-few	many-many
shipment size and transport quantity		medium - high	medium	low
flexibility	time	medium	high	high
	quantity	low	high	high
	space	medium	medium	high

Table 3 - 19: SCP requirements profiles of the three CT concept types.

(A - line transport -regular booking; B - line transport - flexible booking; C - CT network).

Chapter 3 introduces an approach to describe the configuration of a SC concept with regard to the integration of CT. In particular, the impact of certain elements of the sub-concept configurations on the applicability of CT services is concretised. Therefore, chapter 3 serves as the basis for the development of the conceptual research framework presented in the following section.

4 Conceptual Research Framework of Performance-oriented CT Integration into SC Concepts

The fourth chapter aims at the development of a conceptual research framework and the development of propositions on the performance integrated integration of CT into SC concepts. The conceptual framework illustrates the relevant interdependencies between the elements of the SC concepts, the CT concepts as well as integrative measures and instruments with regard to SCP. In a first step, the main research idea is developed based on previous considerations. The section results in the description of the main proposition for the thesis in hand (section 4.1). The conceptual research framework builds on these considerations and follows the argumentation line of configuration theory (section 4.2). In a step-wise approach the central constructs of the research problem are segmented into middle range constructs as well as manifest and observable variables. This procedure differentiates the complex research problem into smaller partial problems. The basic relationships between the main constructs and variables are summarised in first, rather general propositions. These propositions are specified in section 4.3. Here, the relevant cause-and-effect relationships between the elements of the SC and CT concepts as well as integrative measures and instruments are discussed in depth. Section 4.4 summarises the results in the form of intermediate findings.

4.1 Central Aspects of the Development of Research Propositions on the Performance-oriented CT Integration

This section aims at the development of a main research proposition for the performance-oriented integration of CT into SC concepts. The section joins the central findings of the previous chapters and bases the main research propositions on it.

All CT concepts have inherent challenges and general requirements in common. These characteristics restrict the configuration of SC concepts in which CT can be successfully embedded. As shown in section 2.2.1, high and predictable transport quantities with regular demand and comparably long lead times facilitate the integration of CT into SC concepts. However, as shown in section 3.4, these characteristics correspond to the CT concept type of line transport with regular booking (type A). Nevertheless, the introduction of CT business concepts (cf. section 2.2.2.2) and the service-oriented classification of CT concepts (cf. section 3.4) prove that more of

these 'typical' transport characteristics can be met. More flexible CT offers can meet the requirements of shorter lead times, fluctuating demand and transport quantities. Here, for instance, the line CT with flexible booking (type B) is suitable. CT networks (type C) can be applied to rather small transport volumes and comparably long lead times.

One central challenge of CT integration into SC concepts results from the competitive situation with unimodal road transport. The increased time quotas, high coordination efforts as well as additional transshipment, handling and overhead processes result in an increased cost level in comparison with unimodal road transport.

Nevertheless, the potential advantages of CT integration are obvious. Delays induced by congestion and infrastructure shortages in unimodal road transport can be avoided and thus, the transport concept's reliability level can be increased. Furthermore, a SC concept can gain more flexibility by CT integration. CT can be understood as an additional transport mode, which can easily be operated next to unimodal road transport.¹ Owing to the better emissions profile of rail transport in comparison with road transport, the total emissions level can be reduced, depending on the transport distance shifted from road to rail transport. If this advantage is specifically promoted, this effect can positively influence the shipper's image.²

The analysis of recent challenges of SC integration (cf. section 2.1) and CT (cf. section 2.3) shows that CT actors are so far not integrated members of SCs. The conceptual research framework builds on the idea of exploiting this imperfection for the integration of CT into SC concepts. The central argumentation line of the conceptual research framework is based on this consideration.

The tight integration of material and information flow processes can open up time buffers and increase coordination flexibility. There are two approaches to achieve this necessary integration of material and information flows: (1) the alignment of the SC and CT concepts and (2) the situation-specific usage of integrative measures and instruments.

This main research idea can be explained by two basic assumptions:

- (1) The situation-specific adaptation of the SC concept opens up the time requirements for possible CT integration.

¹ cf. Stölzle et al. (2008).

² cf. section 2.3 for further motivations for shippers to integrate CT into their SC concepts.

(2) The SC and CT concept-specific applications of integrative measures generate coordination flexibility and cost savings to reach the SCP level of unimodal road transport.

A conceptual framework supports the specification of these generic assumptions into propositions. The following section describes the development, structures and elements of the framework.

4.2 Development of a Conceptual Research Framework and Deduction of Propositions on the Performance-oriented CT Integration into SC Concepts

A conceptual research framework supports the differentiation of the given complex research problem in partial problems. The development of a conceptual research framework is accomplished in a two-phase process.³ In the first step, all relevant constructs, variables and framework conditions of the research problem are identified (section 4.2). In the second step, the assumed relationships between the constructs and variables are determined (section 4.3). Assumptions on these relationships are concretised in the form of propositions.

4.2.1 Identification of Central Constructs and Framework Conditions

The conceptual research framework illustrates all relevant constructs, elements and dimensions of a given research problem⁴ and visualises the main argumentation line of the thesis in hand.

The conceptual research framework systematises structures, penetrates the problem formulation and supports the development of initial propositions.⁵ The framework joins the preconceptions from the literature review, expert interviews and explorative case studies with the chosen theoretical approach.⁶ The conceptual research framework shows the important elements of the research problem and connects the identified constructs relevant to the problem solution.⁷ The '*fit concept*' of configuration

³ cf. Rössl (1990), pp. 101.

⁴ cf. Kubicek (1977).

⁵ cf. Ibid.

⁶ cf. Wolf (2008), p. 27.

⁷ cf. Kubicek (1977), pp. 37; Wolf (2008), p. 3.

theory serves as the general structure for the framework.⁸ This corresponds to research theory literature on framework design.⁹

Figure 4 - 1 illustrates the relationships between the three main constructs. The design of the conceptual research framework is three-fold. The framework distinguishes context, design and success variables. According to the main research question, the main constructs are '*SC concept*', '*CT concept*' and '*SCP*'. The process of 'integration' is the connecting process element leading to a 'fit'. Additionally '*integrative measures and instruments*' are introduced as 'moderator variables'.¹⁰ It is assumed that each construct can be described more precisely by its elements, dimensions or sub-concepts.

- (1) The SC concept is assumed to be the design variable.¹¹ The design variable is the element that is 'designed' to reach a fit with the framework variable. This assumption follows the considerations of different SC concept configurations in section 3.1.
- (2) The CT concept is assumed to be the framework variable. This assumption follows the considerations of the inherent characteristics of the CT concept presented in section 3.4. The framework variable is assumed to be unalterable. This means for the conceptual research framework that the performance profile of a CT concept is given and cannot be changed.
- (3) The SCP is assumed to be the performance variable. This assumption follows the considerations of the meaning of value and finance orientation in SCM in section 2.3. The performance variable evaluates the quality of the reached fit between the framework and design variables.

Furthermore, *framework conditions* influence the characteristics of the central constructs and thus, the goodness of fit. Building on the consideration in sections 2.2 and 3.1, it is assumed that the SC environment and SC strategy are relevant framework conditions that affect the configuration of SC and CT concept types, the integration process and thus, overall SCP. Figure 4 - 1 gives an overview of the relationship between the central constructs. This general description of the given research problem contributes to answering the main research question.

⁸ cf. section 2.4.

⁹ cf. Wolf (2000), p. 37.

¹⁰ cf. Bortz (2005), pp. 6, 636.

¹¹ cf. Wolf (2008), pp. 345.

As substantiated in section 2.1, the focus of the thesis in hand is to analyse the material and information flow processes and structures¹² rather than the management aspects.¹³ Thus, behavioural aspects and actor-specific problems are excluded from profound consideration. This focus allows the illumination of CT integration potentials rather than actor-specific challenges. The degree of novelty of the research topic, too, recommends this approach to reduce the complexity of the research problem.

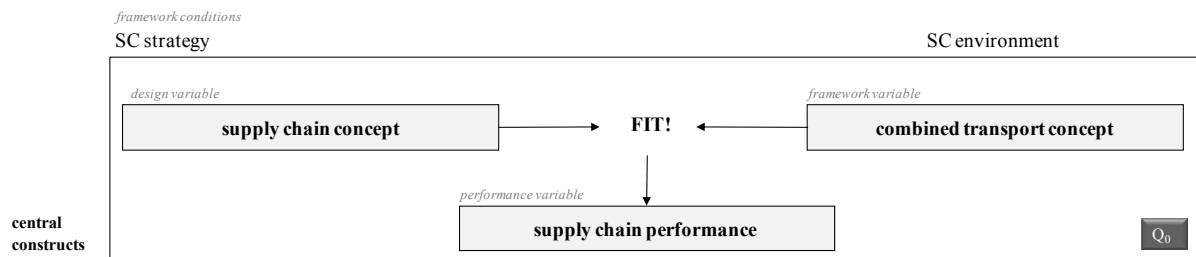


Figure 4 - 1: Central constructs of the CT integration into SC concepts.¹⁴

These considerations lead to the first proposition:

P₁: The better the fit between the SC sub-concepts' configurations and the CT concept types, the higher the level of SCP.

This rather generic framework and the proposition must be concretised. Thus, the following section introduces so-called '*middle range constructs*' for specification.

4.2.2 Middle Range Constructs — Elements and Dimensions of Central Constructs

The central constructs of the conceptual research framework are further concretised by '*middle range constructs*'. These middle range constructs are based on the typologies for SC and CT concepts. This specification is the basis for the deduction of detailed propositions. A selection of these propositions is analysed in depth in the simulation study presented in chapter 5.

Following the procedure and terminology of configuration theory (cf. section 2.4), the SC concept is defined as the design variable. It is concretised by its embedded sub-concepts (cf. section 3.3) of the:

¹² Following the deliberations of Cooper et al. (1997) and Lambert et al. (2001), both the SC concept and CT concept can be distinguished by concept structure, concept processes and concept management. cf. Cooper et al. (1997), p. 177; Lambert et al. (2001), p. 71. This understanding corresponds to the presented typologies of SC concepts (section 3.3), CT concepts (section 3.4) and SCP understanding (section 2.2).

¹³ cf. Lambert et al. (2001).

¹⁴ Own illustration.

- (1) Procurement concept, (cf. section 3.3.3),
- (2) Production concept, (cf. section 3.2.4),
- (3) Distribution concept (cf. section 3.2.5) and
- (4) Embedded and linking transport concepts. (cf. section 3.2.2).¹⁵

It can be assumed that the configuration of these sub-concepts influences the applicability of CT and thus SCP.

The CT concept is assumed to be the *framework variable*. The classification of CT concepts was introduced in section 3.4. Three CT concept types were identified:

- (1) Regular line trains – regular booking,
- (2) Regular line trains – flexible booking and
- (3) CT networks.

It can be assumed that the applicability and effect on SCP differ according to the CT concept type.

SCP is chosen as the *performance variable* for the evaluation of the fit between SC and CT concepts. As shown in section 2.3.1, the SCP term can distinguish between efficiency and effectiveness. This means that the effect of the CT integration into a SC concept is evaluated according to these two dimensions. This two-dimensionality does justice to the principle of equifinality (cf. section 2.4). There are different possible approaches for a given initial situation since SCP is situation- and actor-specifically defined.

Figure 4 - 2 provides an overview of the middle range constructs. Furthermore, the typologies of SC sub-concepts and CT concepts contribute to answering the second research question.

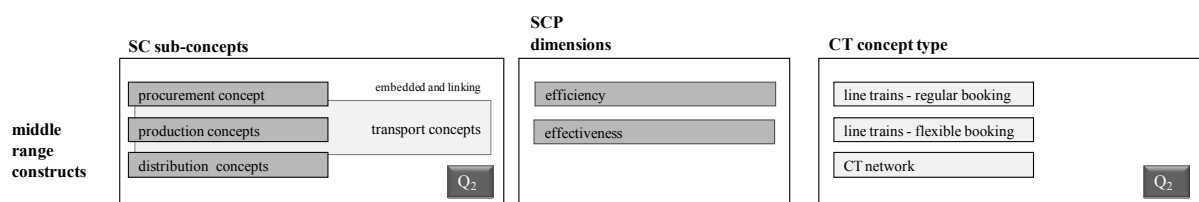


Figure 4 - 2: Middle range constructs of the performance-oriented CT integration into SC concepts.¹⁶

The middle range constructs must be concretised by manifest and observable vari-

¹⁵ This means that a CT concept must be understood as a part of the specific SC concept itself. Furthermore, the impact of different sub-concept configuration on specific SCP requirements has been discussed.

¹⁶ Own illustration.

ables. This is necessary to develop more detailed propositions.

4.2.3 Manifest, Observable Variables

The middle range constructs are further specified by manifest and observable variables. The measurability of these variables is the requirement for the development of first propositions.

To evaluate different configurations of sub-concepts six primary and two secondary dimensions of SCP requirements were empirically identified (the deductions of these requirements is presented in section 3.2). There are eight categories for the analysis of the SCP requirements of the sub-concepts, namely the procurement, production and distribution concept and the linking and embedded transport concepts. The different configurations can be understood as '*SCP requirements profiles*' (Figure 4 - 3, left). This structured description of SCP requirements contributes to answer the first research question.

Corresponding to the SCP requirements profiles, there are eight dimensions for the analysis of different CT concepts. Different configurations can be expressed by so-called '*CT performance profiles*' (Figure 4 - 3, right; deduction of the performance profiles in 3.4).

The evaluation of the SCP is accomplished by means of seven performance indicators. The performance indicators reflect the characteristics of performance measurement in a CT context and the concept of SCP management. (cf. deduction in section 2.3.5).

- (1) Adherence to schedules
- (2) Inventory levels
- (3) Utilisation of capacities
- (4) Lead time
- (5) Flexibility (on short-term changes)

These key figures above focus on the integration of material and information flows. However, to do justice to the SCP focus on financial key figures and the meaning of sustainable behaviour for the image of the SC actors, two more key figures are added:

- (6) Costs (e.g., process costs, capital commitment) and
- (7) Emissions (e.g., CO₂, NO_x and particles)

Key figures (1) – (3) can be assigned to the effectiveness dimension. Key figures (4) – (7) can be assigned to the efficiency dimension (cf. Figure 4 - 3).

In practice, the weighting of these key figures must be accomplished for company, SC and situation. Generally, the thesis in hand does not evaluate and weight the importance of these key figures. However, the meaning of different key figures is discussed for the standardised logistics and SC concepts introduced in chapter 3.

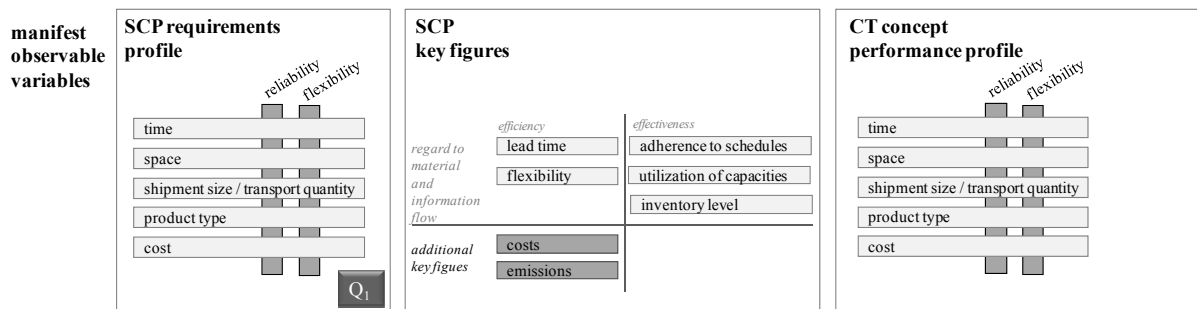


Figure 4 - 3: Manifest, observable variables of CT integration into SC concepts.¹⁷

These considerations lead to two more detailed propositions. These propositions take special regard of the developed key figures.

P₂: The better the fit between SC concept and CT concept, the higher SC efficiency in terms of (a) shorter SC lead times, (b) higher SC flexibility, (c) lower SC costs and (d) lower SC emissions.

P₃: The better the fit between SC concept and CT concept, the higher SC effectiveness in terms of a better achievement of the defined level of (a) adherence to schedules, (b) capacity utilisation and (c) inventory levels.

Figure 4 - 4 summarises the findings of the conceptual research framework. The following section builds on the illustration of dependencies between the central constructs on all three consideration levels.

¹⁷ Own illustration.

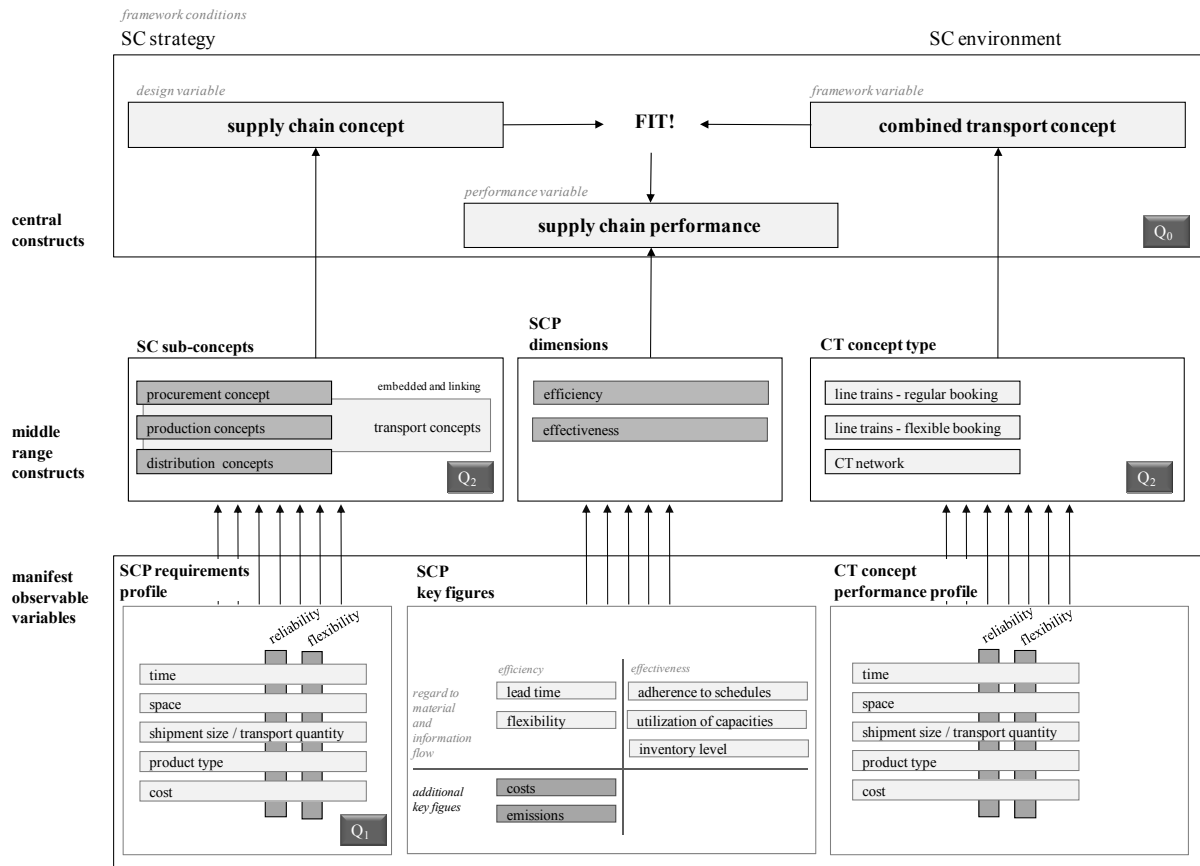


Figure 4 - 4: Conceptual research framework of CT integration into SC concepts.¹⁸

The following section introduces a moderating variable of the fit between SC and CT concept. More precisely, integrative measures and instruments are introduced as moderating variables.

4.2.4 Moderating Variables of CT Integration into SC Concepts

In this section, the meaning of integrative measures and instruments for CT integration into SC concepts is specified. Therefore, an additional element is appended to the conceptual research framework. The technical and organisational management components for SCM, introduced in section 2.1.6, are assumed to be moderating variables. This means that the integrative measures influence the fit between SC and CT concept. This contributes to answering the third research question. Figure 4 - 5 illustrates the considerations on the effect of integrative measures and instruments on the fit between SC and CT.

¹⁸ Own illustration.

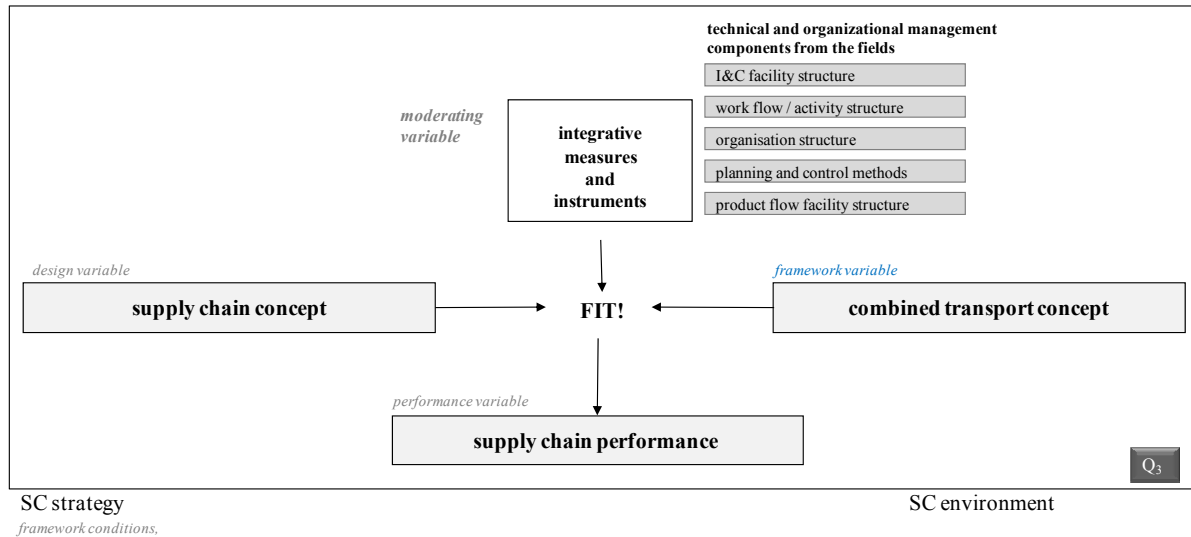


Figure 4 - 5: Integrative measures and instruments as moderating variables for CT integration.¹⁹

The technical and organisational management components influence the integration process. If the integrative measures are suitable for the given configuration of SC and CT concept, the usage can improve SCP. The management components are integrative measures and instruments. There are five groups of integrative measures, introduced in section 2.1.6:

- (1) I&C facility structure,
- (2) Workflow & activity structure,
- (3) Organisational structure,
- (4) Planning and control methods and
- (5) Product flow facility structure.

Following the considerations in section 2.1.6, the integrative measures are assumed to impact all performance dimensions of CT integration. Thus, there are two propositions on the effect of integrative measures.

P₃: The better the fit of integrative measures and instruments and the configuration of SC concept and CT concept, the higher SC efficiency in terms of (a) shorter SC lead times, (b) higher SC flexibility, (c) lower SC costs and (d) lower SC emissions.

P₄: The better the fit of integrative measures and instruments and the configuration of SC concept and CT concept, the higher SC effectiveness in terms of the better the achievement of the defined level of (a) adherence to schedules,

¹⁹ Own illustration.

(b) capacity utilisation and (c) inventory levels.

Propositions P_1 to P_3 have rather general characters. They are statements on the general cause-and-effect relationships, but are not specific enough to be transferred to practical recommendations. Thus, the following section analyses the cause-and-effect relationships between the elements of the conceptual research framework in depth.

4.3 Cause-and-Effect Relationships between the Elements of CT and SC Concepts - Deduction of Methodological and Instrumental Implications

This section builds on the propositions P_1 to P_3 to analyse the cause-and-effect relationships between SC and CT concepts as well as the impact of integrative measures and instruments on the fit. This aims at the development of specified propositions and at the development of practice-oriented recommendations for CT integration into SC concepts. Thus, the section contributes to answering the third research question. Therefore, a four-step approach is applied.

The progressive approach includes:

- (1) The identification of integration points for CT into SC concepts,
- (2) The impact of SC strategy, SC concept configuration and SCP requirements profiles for CT integration,
- (3) The identification of adaptation points of SC sub-concepts to change SCP requirements profiles with regard to the typology of CT concepts and
- (4) The situation-specific effects of integrative measures and instruments on SCP.

The results of these considerations are summarised in the form of propositions.

4.3.1 Step 1: Identification of Integration Points for CT into SC Concepts

In a first step, the general integration points for CT into SC concepts are identified. The definition of specific integration points allows keeping the number of developed propositions low. These four types characterize different types of CT integration situations. Figure 4 - 6 gives a schematic illustration of the integration points.

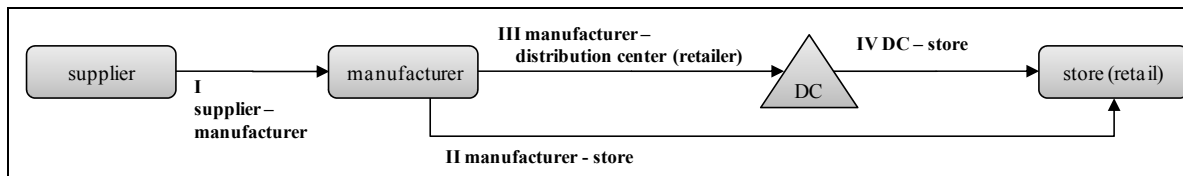


Figure 4 - 6: Schematic illustration of the integration points of CT concepts.²⁰

I. supplier - manufacturer

CT concepts can be integrated for the material flow processes between the supplier's and manufacturer's production site. Therefore, the configuration of the production concepts, the manufacturers' procurement concepts and the supplier's distribution concept are relevant.

II. manufacturer - store

CT concepts can be integrated to ensure the material flow processes between the manufacturer's production site and the retailer's store. Therefore, the configuration of the manufacturer's production and procurement concepts as well as the retailer's distribution concept are relevant.

III. manufacturer - DC

CT concepts can connect the manufacturer' production site and the retail's DC. The differentiation to the previous integration point (II) is necessary, since store delivery and DC delivery can significantly differ in terms of SCP requirements regarding the embedded and linking logistics and transport concepts.

IV. DC - store

CT concepts can be integrated to connect the DC with the store. The configuration of the retailer's distribution concept is central for the integration.

The classification of possible integration points delivers information on the involved SC sub-concepts. The sub-concepts determine the specific SCP profiles to be met by the CT performance profiles. Thus, the targeted adaptation of the sub-concepts contributes to a performance-oriented CT integration into SC concepts. Table 4 - 1 summarises the considerations in a schematic overview of the relevant sub-concepts, which have to be taken into consideration for a performance-oriented CT integration into SC concepts.

²⁰ Own illustration.

Integration point	I	II	III	IV
SC strategy	supplier - manufacturer	manufacturer-store	manufacturer - DC	DC - store
production concept supplier	X			
distribution concept supplier	(X)			
procurement concept manufacturer	(X)			
production concept manufacturer	X	X	X	
distribution concept manufacturer		(X)	(X)	
procurement concept retailer		(X)	(X)	
distribution concept retailer		X	X	X

Table 4 - 1: Identification of relevant concepts depending on the integration point. (X = primary impact; (X) = secondary impact).

4.3.2 Step 2: Impact of SC Strategy, SC Concept Configuration and SCP Requirements Profiles on CT Integration

In a second step, general recommendations on the suitability of certain SC strategies for CT integration are developed. Since SC concepts are defined as the operationalisation of SC strategies, initially, the applicability is determined by demand and supply characteristics, namely predictability and lead times.

The SC strategy impacts the central supply and demand characteristics in a SC, which are relevant for CT integration, such as the *predictability* of transport volumes, times and frequencies as well as the *lead times*. Figure 4 - 7 visualises the general applicability of CT into SC concepts according to different SC strategies. The classification of SC strategies can be affiliated to two main criteria: predictability of demand and length of lead times.

Generally, SCs with lean strategies (type I – plan and optimize and type II – continuous replenishment) are suitable for the integration of CT because of the high level of demand predictability. The lean (type I) strategy and the leagile strategy are suitable for the integration of CT because of their comparably long lead times. The integration into SC concepts with an agile SC strategy seems to be rather difficult because the characteristics of the SC and CT concept configurations are rather contrary.

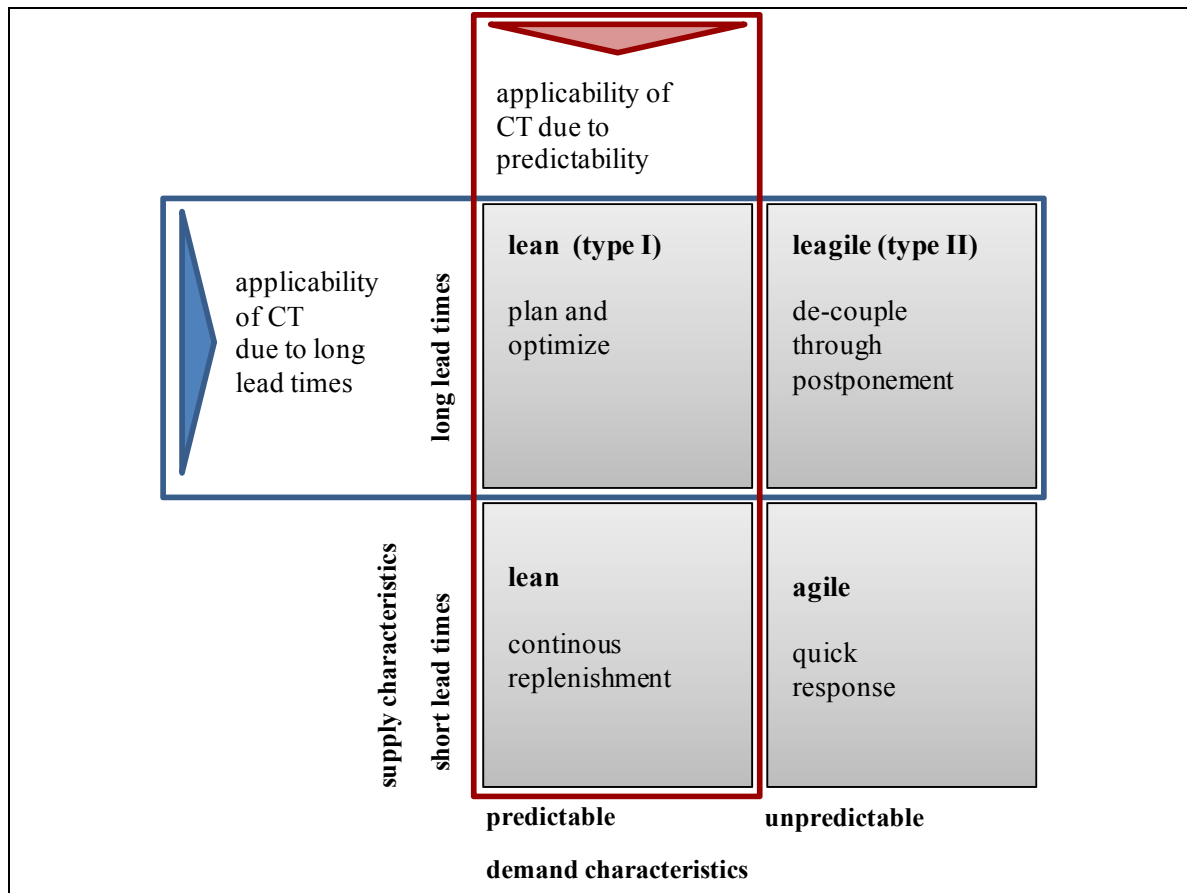


Figure 4 - 7: General applicability of CT concepts according to different SC strategies.²¹

These considerations give first guidance on the general applicability of CT concepts into a certain SC concept.

Next to the SC strategy, the integration point is central for the integration of a CT into a SC concept.

(I) The material flow processes *between supplier and manufacturer* in a lean and a leagile SC are characterised by rather high transport volumes as well as regular and long lead times.²² The integration of regular line transport is suitable if the daily, weekly or more frequently transport quantities reach a FTL level. In a lean (type I - plan and optimize) environment, CT networks can also be used for smaller shipment sizes. In an agile SC, depending on shipment size, transport relation and delivery time, flexible line trains can be applied to the rather fluctuating transport quantities.

(II) The material flow processes *between manufacturer and stores* is characterised by

²¹ With significant enhancements on the basis of Christopher (2005b).

²² Assuming the customer decoupling point is downstream of the SC.

rather small transport quantities. Stores usually have no warehouse capacities to hold transport goods. Shipping to the store directly from a production site is only common for predictable and medium-sized transport volumes, namely in a lean SC (type I - plan and optimize). This means the shipment size is usually LTL. Thus, the required transport volume for line transport is usually not reached. However, for comparably large stores with regular transport volumes (FTL) the integration of regular line transport can be possible. Furthermore, the sporadic integration, e.g., in the case of specific promotion activities, with flexible line concepts is applicable. For long lead times and packaged goods the usage of a CT network is appropriate.

In lean SC (type II - continuous replenishment) and leagile SCs²³ with short lead times, the integration of CT between manufacturer and store is generally not applicable. However, depending on the situation-specific framework conditions for comparably long lead times and smaller transport quantities the integration of CT networks can be possible.

(III) The material flow between *manufacturer and a retailer's DC* is characterised by *comparably* high transport volumes. In particular, in lean SCs the integration of regular line transport is conceivable depending on transport quantities and frequency. For smaller transport quantities with comparably long lead times (lean type I - plan and optimize), the usage of CT networks is also possible.

For this integration point the differentiation of leagile SCs into SCs with manufacturing and logistics postponement strategy is necessary. For the delivery between manufacturer and store a leagile SC with manufacturing postponement is characterised by rather fluctuating and smaller transport quantities. Thus, depending on the other framework conditions line transport with flexible booking and CT networks are applicable. In a logistics postponement environment, transport quantities have a rather lean character. Thus, the application of line transport with regular booking and for comparably long lead times and small shipment sizes the usage of CT networks is possible. In an agile SC depending on the specific transport quantities only the flexible line transport and the CT network may reflect the fluctuating transport quantities.

(IV) The material flow between *DC and store* is characterised by rather small transport quantities. In lean SCs, the introduction of regular line transport is sensible. In a

²³ Assuming the customer decoupling point is upstream of the SC.

lean SC (type I - plan and optimize) with comparably long lead times, the sporadic usage of flexible line trains, e.g., for promotion activities, is also conceivable. In leagile and agile SCs, the delivery between DC and store is characterised by responsiveness and speed. Thus, the integration of CT would contradict these ideas.

Table 4 - 2 summarises these considerations and provides general recommendations on the CT concept types into SCs with different SC strategies.

Integration point	I	II	III	IV
SC strategy	supplier - manufacturer	manufacturer-store	manufacturer - DC	DC - store
lean I (plan and optimize)	A, C	(A), (B), C	A, C	A, (B)
lean II (continuous replenishment)	A,	-	A	A
leagile I (manufacturing postponement)	A	-	B, C	-
leagile II (logistics postponement)	A	-	B	-
agile	(B)	(C)	(B), (C)	-

Table 4 - 2: Applicability of CT types according to SC strategy and integration point.

A = line trains – regular offer; B = line trains – flexible offer; C = CT network; A applicable; (A) applicable in limited extend

These considerations are of rather generic character and do not regard specific framework conditions. The following section builds on these generic recommendations and identifies adaptation possibilities to improve the fit between a specific SC concept and a specific CT concept.

4.3.3 Step 3: Identification of Adaptation Points for CT Concept Integration

In the previous section, a general fit between different SC and CT concept types was discussed. However, to practically integrate CT into a SC concept the SCP requirements profile of the SC concept and the SCP profile of the CT concept must be compared. This comparison shows the fits or misfits regarding certain SCP requirements. Thus, in the following section, the adaptation points for influencing the SC concept configuration are introduced to overcome any identified '*misfits*'.

Example of the Identification of Adaptation Points

Table 4 - 3 provides an example of profile comparison. Here, the general SCP requirements profile of a lean SC (type I - plan and optimize) and the performance profile of a line transport concept with regular booking concept are contrasted. Table 4 - 2 shows that the combination of a lean SCP requirements profile fits with the CT performance profile regarding all performance criteria.

dimension	performance criteria	lean I SC concept – SCP requirements	line trains – regular booking – CT performance profile	fit ?
time	delivery window	long	high	√
	transport time	long	high	√
	delivery frequency	low	high	√
space	transport distance	lon	short	√
	distance to infrastructure connection	long	short	√
	number of sources and destinations	low	few-few	√
quantity	shipment size /transport quantity	high	medium - high	√
product type		standard	standard	√
costs	transport cost / turnover	high	medium	√
flexibility	time	low	medium	√
	quantity	low	low	√
	space	low	medium	√
reliability	adherence to schedule	medium	high	√
	quality	medium	high	√

Table 4 - 3: Example of contrasting lean SCP requirements profile and the performance profile of line transport concept with regular booking performance profile (√ = general fit; X = misfit).

Nevertheless, the comparison of the level of specific performance requirements may show misfits resulting from the situation-specific framework conditions. For instance, there may be misfits regarding the SCP requirements in the time dimension, which cannot be met by the chosen CT concept (Table 4 - 4). In this example, the SC concept requires short transport times, whereas the CT concept offers medium transport times. Furthermore, the SC concept requires more frequent deliveries.

dimension	performance criteria	SCP requirements	CT performance	fit?
time	delivery window	long	high	√
	transport time	short	medium	X
	delivery frequency	high	medium	X

Table 4 - 4: Example of the misfit of SCP requirements and CT performance profile.

Following configuration theory, the time dimension of the CT concept is assumed to be the framework variable and thus unalterable. The SC concept is defined as the design variable. This means for the given example that the requirements of the default transport time and delivery frequency must be adapted if the integration of CT is desired.

In sections 3.3.2, 3.4.2 and 3.5.2, different adaptation points for the SC sub-concepts, namely the procurement, production and distribution concepts, are identified. Table 4 - 5 summarises the findings for time-related SCP requirements.

dimension	performance criteria	procurement concept	production concept	distribution concept
time	delivery window	<ul style="list-style-type: none"> • supplier choice • procurement area • procurement time 	<ul style="list-style-type: none"> • order release • release of secondary demand • production control logic 	<ul style="list-style-type: none"> • delivery time point
	transport time	<ul style="list-style-type: none"> • procurement area • procurement time 	<ul style="list-style-type: none"> • order release • release of secondary demand • stocking type 	<ul style="list-style-type: none"> • regional structure • echelon structure • delivery service • delivery time point
	delivery frequency	<ul style="list-style-type: none"> • supplier choice • procurement time 	<ul style="list-style-type: none"> • order release • release of secondary demand • stocking type 	<ul style="list-style-type: none"> • regional structure • echelon structure

Table 4 - 5: Adaptation points for SCP requirements regarding time.
(developed in sections 3.3.2, 3.4.2 and 3.5.2).

This means that to adapt the performance requirements regarding transport time, depending on the integration point (cf. section 4.31.; Figure 4 - 6: (I) supplier – manufacturer, (II) manufacturer - store, (III) manufacturer – DC, (IV) DC – store), there are different adaptation points. For the delivery between supplier and manufacturer, the manufacturer’s procurement concept can be adapted (cf. Table 4 - 1). This means for the alignment of transport times supplier choice, procurement area and procurement time can be altered (cf. section 3.3.2.3). Furthermore, the adaptation of the production concept in terms of order release, secondary order release and stocking type is possible (cf. section 3.4.2.3). Finally, the adaptation of the supplier’s distribution concept is possible. For instance, delivery service, regional structure and echelon structure could be altered to influence the required transport and thus, the fit with the CT concept (cf. section 3.5.2.3).

Depending on the specific framework conditions there may be misfits regarding all identified SCP requirements. These misfits give advice about the alignment of performance requirements and characteristics. Specific adaptation points can be activated to counteract these misfits. In sections 3.3 to 3.5 for each SC sub-concept, adaptation possibilities and their effects on the specific SCP requirement dimensions were worked out. Figure 4 - 6 presents these findings structured according to the SC sub-concept and the different performance dimensions.

Product type is a central requirement for transport concepts. The decision over a certain product type is of strategic nature (cf. section 3.1). Thus, for the discussion of the impact of the SC sub-concept configuration it is assumed that product type cannot be influenced by the adaptations to sub-concepts (cf. section 3.2).

dimension	performance criteria	procurement concept	production concept	distribution concept
time	delivery window	<ul style="list-style-type: none"> supplier choice procurement area procurement time 	<ul style="list-style-type: none"> order release release of secondary demand production control logic 	<ul style="list-style-type: none"> delivery time point
	transport time	<ul style="list-style-type: none"> procurement area procurement time 	<ul style="list-style-type: none"> order release release of secondary demand stocking type 	<ul style="list-style-type: none"> regional structure echelon structure delivery service delivery time point
	delivery frequency	<ul style="list-style-type: none"> supplier choice procurement time 	<ul style="list-style-type: none"> order release release of secondary demand stocking type 	<ul style="list-style-type: none"> regional structure echelon structure
space	transport distance	<ul style="list-style-type: none"> supplier choice procurement area 		<ul style="list-style-type: none"> regional structure echelon structure
	distance to infrastructure connection	<ul style="list-style-type: none"> supplier choice 		<ul style="list-style-type: none"> regional structure echelon structure
	number of sources and destinations	<ul style="list-style-type: none"> supplier choice 		<ul style="list-style-type: none"> regional structure echelon structure
quantity	shipment size and transport quantity	<ul style="list-style-type: none"> supplier choice procurement time 	<ul style="list-style-type: none"> order release stocking type production control logic 	<ul style="list-style-type: none"> regional structure echelon structure
cost	transport cost / turnover	<ul style="list-style-type: none"> supplier choice procurement area procurement time incoterms 	<ul style="list-style-type: none"> release of secondary demand 	<ul style="list-style-type: none"> regional structure echelon structure delivery service
flexibility	time	<ul style="list-style-type: none"> supplier choice procurement area procurement time incoterms 	<ul style="list-style-type: none"> order release release of secondary demand stocking type production control logic 	<ul style="list-style-type: none"> regional structure echelon structure delivery service
	quantity	<ul style="list-style-type: none"> supplier choice procurement time 	<ul style="list-style-type: none"> order release release of secondary demand stocking type production control logic 	<ul style="list-style-type: none"> delivery service regional structure echelon structure
	space	<ul style="list-style-type: none"> supplier choice procurement area 		<ul style="list-style-type: none"> regional structure
reliability	adherence to schedules	<ul style="list-style-type: none"> supplier choice procurement area procurement time 	<ul style="list-style-type: none"> stocking type production control logic 	<ul style="list-style-type: none"> delivery service
	quality	<ul style="list-style-type: none"> supplier choice procurement area incoterms procurement time 	<ul style="list-style-type: none"> production control logic 	

Table 4 - 6: Adaptation points according to performance dimension, criterion and involved SC sub-concept. (developed in sections 3.3.2, 3.4.2 and 3.5.2).

Next to these adaptation points, integrative measures and instruments can be utilised to influence the fit between SC and CT concepts.

4.3.4 Step 4: Situation-specific Choice of Integrative Measures and Instruments for Performance-oriented CT Integration into SC Concepts

This section addresses the effect of integrative measures and instruments on the integration of CT into SC concepts. The integrative measures and instruments introduced in section 2.1.6 are analysed regarding their impact on specific SCP requirements. Thus, the section specifies the findings of the effects of integrative measures and instruments for the research problem on the integration of CT into SC concepts. The findings can be understood as practical recommendations for the targeted usage of integrative measures and instruments. The section provides a selection basis as well as an outlook on the expected effect of the measures. Thus, this section answers the third research question.

'Integrative measures and instruments' were introduced as moderating variables in the conceptual framework depicted in Figure 4 - 5. This means that the integrative measures cannot impact the fit or misfit in general, but improve the goodness of fit (cf. argumentation in section 4.1). The goodness of fit results from the impact of the integrative measures and instruments on single SCR requirements criteria.

Section 2.1.6 introduces 13 categories of integrative measures and instruments suitable for application in a SC concept including CT. Table 4 - 7 provides an overview of the integrative measures and instruments and introduces a numbering as an abbreviation for the following tables.

integrative measure and instrument group	abbreviation	measures and instruments
I&C flow facility structure	1	integrated I&C methods, technologies and systems
	2	online platforms and online data provision
	3	automatic identification technologies
	4	standardisation of I&C technologies
workflow facility structure	1	online or electronic data interchange (EDI)
	2	latest material flow equipment / technologies
	3	standardisation activities
	4	SC-wide quality standards
	5	collaborative improvement techniques
organisational structure	1	cross-company operational activities
	2	strategic integrative activities
planning and control methods	1	joint planning and control systems
	2	joint planning and control approaches
	3	modelling and simulation techniques
product flow facility structure		product and load carrier design

Table 4 - 7: Overview of analysed integrative measures and instruments and abbreviations. (developed in section 2.1.6).

Impact of Integrative Measures and Instruments on Time Aspects

Performance requirements of the 'time' dimension can be positively influenced by all types of integrative measures. The application of latest and *integrated I&C methods*, technologies and usage accelerates information exchange and communication times and serves as the basis for the application of cross-company planning and control approaches. These targeted collaborative activities reduce planning, handling and transport efforts in all SC parts and thus, positively influence the different lead time parts, such as transport time and production time. The usage of online platforms accelerates order placing and processing. Online data provision reduces waiting times and allows, even in the case of delays, the planning and control of delivery windows. The precise cross-company calculation of material flow processes allows the definition and meeting of short delivery windows²⁴ because of the better forecasting possibilities and online planning approaches.²⁵

Measures of the category '*workflow / activity structure*' are the most obvious approach for the acceleration of lead and transport times. Practical examples include '*business process reengineering*' or '*process optimisation*' projects.²⁶ The introduction of online or EDI solutions accelerates information flow processes. As a result, cross-company material flows can be closer coupled and lead times can be decreased. Furthermore, it is the basis of cross-company planning approaches and thus, positively influences the meeting of time windows. The usage of the latest and standardised material flow equipment and technologies, e.g., load carriers and conveyors, reduces waiting and transition times and thus, delays in material flow at the interfaces between SC actors. For instance, the application of the latest load carriers and transshipment technologies enables the handling of hazardous or frozen goods. In particular, the introduction of SC-wide quality standards, for instance for the EN ISO 9001:2008 or industry-specific quality norms such as the VDA 6.1 (automotive), harmonises the material flow and can even shorten lead times, since control processes can be reduced.²⁷ The continuous improvement of the cross-company process integration of material and information flows supports obtaining the long-term fit of CT and SC.

²⁴ cf. Zobel (2011); Quak et al. (2009).

²⁵ cf. Campbell et al. (2004); Chan et al. (2011); Wang et al. (2008).

²⁶ cf. Davenport (1993); Jonsson et al. (2007); Neiro et al. (2004); Papageorgiou (2009); Shobryns et al. (2002).

²⁷ cf. Bessant et al. (1994); Dowell et al. (2000); Jayaraman et al. (1999); Kaijie et al. (2007); Kim (2009); Parsons (2002).

Operative cross-company organisational measures, such as the introduction of project teams, decrease communication, reaction and decision times and thus, shorten and stabilise transport and total lead times.

Planning and control methods are central aspects to influence time-related SCP requirements. Based on the availability of EDI and general I&C systems, joint planning and control systems (e.g., ERP, PPC and APS systems and modules) as well as corresponding planning and control approaches significantly influence the design of delivery times and frequencies as well as lead times. Modelling and simulation techniques are used to improve the cross-company understanding of material and information flow processes. The encompassing understanding of the relevant cause-and-effect relationships is the basis for all optimising and aligning activities for the integration of material and information flows in a SC including CT. Thus, indirectly modelling and simulation techniques influence all time-related SCP requirements.

The '*product flow facility structure*' is central for the time aspects of SCP requirements since the network structure impacts transport times and thus, lead times. Furthermore, this means the logistics-oriented design of products or load carriers can significantly reduce handling times. Table 4 - 8 summarises the considerations of the impact of integrative measures and instruments on time-related SCP requirements.


 SCP requirements dimension		Impact of integrative measures and instruments on														
		I&C facility structure				workflow / activity structure					organisa-tional structure		planning and con-trol methods			product flow facility structure
		1	2	3	4	1	2	3	4	5	1	2	1	2	3	
time		+			+					+		+			+	
	window	+	+	o	o	+	o	o	+	o	o	o	+	+	(+)	o
	lead time	+	+	+	o	+	+	+	+	+	+	o	+	+	(+)	+
	frequency	o	o	o	o	o	o	o	o	o	o	o	+	+	(+)	o

Table 4 - 8: Impact of integrative measures and instruments on time-related SCP requirements.
 (+ positive impact; - negative impact; +/- negative or positive impact to be weighed up (depending on framework conditions); o no relevant impact; () indirect impact)

Impact of Integrative Measures and Instruments on Space Aspects

Integrative measures of *organisational structure* and *product flow facility structure* are suitable to influence shippers' SCP requirements regarding the '*space*' dimension to allow the integration of CT into a SC concept.

The joint design of the SC network (for instance, the definition of locations for transshipment or storage facilities) improves the spatial responsiveness of the SC. To meet SCP requirements regarding location and distance for the freight transport integrative measure of the *product flow facility structure* category as well as *workflow / facility*

structure measures are suitable. Through the joint design of the SC network (for instance, the definition of locations for transshipment or storage facilities) improves the spatial responsiveness of the SC. For instance, in Zermatt, Switzerland, two Swiss retailers and a private rail transport company collaboratively designed, planned, built and operate a CT terminal for the delivery of the Alp-city with goods.²⁸ Table 4 - 8 summarises the considerations of the impact of integrative measures and instruments on space-related SCP requirements.


 SCP requirements dimension		Impact of integrative measures and instruments on														
		I&C facility structure				workflow / activity structure					organisa-tional structure		planning and con-trol methods			product flow facility structure
		1	2	3	4	1	2	3	4	5	1	2	1	2	3	
space		o				o					+		o			o
	distance	X				X					o +		X			X
	location										o +					
	no. of sites										o +					

Table 4 - 9: Impact of integrative measures and instruments on space-related SCP requirements.
 (+ positive impact; - negative impact; +/- negative or positive impact to be weighed up (depending on framework conditions); o no relevant impact; () indirect impact)

Impact of Integrative Measures and Instruments on Shipments Size and Transport Quantity

The product and demand are central for the definition of shipment size and entire transport quantity. As discussed in section 3.1, the product itself as well as the demanded quantities can be influenced neither by the SC concept design nor by the usage of integrative measures and instruments. However, the integrative measure of product flow facility structure can influence shipment size and thus, transport quantity. For instance, the choice of specific load carriers and a logistics-oriented product design influence the utilisation of transport capacities and thus, shipment size. The usage of transport planning approaches for route planning, capacity planning and so on can improve the utilisation of vehicles. Thus, transport quantities and shipment size can indirectly be influenced. Table 4 - 10 summarises the considerations of the impact of integrative measures and instruments on shipment size and quantity-related SCP requirements.

²⁸ cf. 1815.ch (2011); Bahnonline (2011).


 SCP requirements	Impact of integrative measures and instruments on														
	I&C facility structure				workflow / activity structure					organisa-tional structure		planning and con-trol methods			product flow facility structure
	1	2	3	4	1	2	3	4	5	1	2	1	2	3	
shipment size / transport quantity	o				o					o		(+) (+) o			+
															+

Table 4 - 10: Impact of integrative measures and instruments on shipment size and transport quantity related SCP requirements.

(+ positive impact; - negative impact; +/- negative or positive impact to be weighed up (depending on framework conditions); o no relevant impact; () indirect impact)

Impact of Integrative Measures and Instruments on Costs

The 'cost' dimension is affected by all integrative measures. Often, transaction cost theory is applied to explain both the positive and negative impacts of measures on the cost dimension. Costs are generated before, during and after the application of integrative measures and instruments. These short-term costs must be balanced with the generated cost advantages and further positive effects on SCP in the mid- and long-term.

As shown in section 2.1.6, the integration of cross-company I&C approaches significantly influences SC costs. The planning, design, implementation and operation of I&C systems causes significant costs, but in the long-term I&C systems reduce process costs. As shown, the usage of cross-company I&C systems as well as online platforms and online data provision can reduce planning, control and monitoring effort and thus, reduce costs. The usage of auto ID technologies reduces handling processes, but causes costs for the necessary equipment (antennas, tags, etc.) and I&C systems. The standardisation of I&C technologies is the basis to reduce interface problems and to integrate the cross-company information flow between CT actors and shippers.

Integrative measures regarding the 'workflow facility structure' positively influence the cost dimension of SCP requirements. Usually, before a SC actor makes significant modifications to the process structure, the profitability and amortisation time for investments is analysed. Hence, a solely positive effect of this type of integrative measures can be assumed. Online and EDI as well as new material flow equipment / technologies (e.g., for transport and transshipment) cause initial costs to be balanced by cost savings in the long-term. The standardisation of technologies and quality management as well as the introduction of continuous improvement techniques reduce costs because of fewer interface problems and less process disturbances. The introduction of a SC-wide quality management with consistent standards improves the

efficiency of business processes, reduces process disturbances and thus, reduces costs.

In the short-term, *organisational measures* increase costs. In the mid- and long-term, these costs can indirectly be saved, for instance, by reducing communication and planning times. Thus, organisational measures are thought to negatively affect the cost dimension.

Integrative measures from the field of '*planning and control methods*' simplify and accelerate material and information flow processes. This reduces overall SC costs. However, specific investments are necessary and operating costs must be included in the efficiency analysis. Owing to this conflicting impact, measures are classified as indifferent according to the specific framework variables of CT and SC concepts. Table 4 - 8 summarises the considerations of the impact of integrative measures and instruments on cost-related SCP requirements.


reading direction  SCP requirements	Impact of integrative measures and instruments on														
	I&C facility structure				workflow / activity structure					organisa-tional structure		planning and con-trol methods			product flow facility structure
	1	2	3	4	1	2	3	4	5	1	2	1	2	3	
cost	+/-				+					-		+/-			+/-
	+/-	+/-	+/-	+	+/-	+/-	+	+	+	-	-	+/-	+/-	o	+/-

Table 4 - 11: Impact of integrative measures and instruments on cost related SCP requirements.
 (+ positive impact; - negative impact; +/- negative or positive impact to be weighed up (depending on framework conditions); o no relevant impact; () indirect impact)

Impact of Integrative Measures and Instruments on Product Type

In particular, the integrative measures of '*workflow facility structure*' and '*product flow facility structure*' influence the performance requirements of the '*product type*' dimension. The usage of the latest material flow technologies and *standardisation activities* positively affect the good's quality. In particular, the application of latest load carriers and transshipment technologies enables special transport, such as that of hazardous or frozen goods. The standardisation of technologies reduces the handling effort and problems at the system interfaces and thus, improves quality. The introduction of SC-wide *quality management* improves the quality of products and services. *Improvement techniques* aim to develop product quality. Table 4 - 12 summarises the considerations of the impact of integrative measures and instruments on product-related SCP requirements.


reading direction  SCP requirements	Impact of integrative measures and instruments on														
	I&C facility structure				workflow / activity structure					organisa-tional structure		planning and con-trol methods			product flow facility structure
	1	2	3	4	1	2	3	4	5	1	2	1	2	3	
product	o				+					o		o			+
	X				o	+	+	+	+	X		X			+

Table 4 - 12: Impact of integrative measures and instruments on product related SCP requirements. (+ positive impact; - negative impact; +/- negative or positive impact to be weighed up (depending on framework conditions); o no relevant impact; () indirect impact)

Impact of Integrative Measures and Instruments on Flexibility

The SCP requirements of the flexibility dimension can be influenced by all categories of integrative measures and instruments.

The measures of *I&C facility structure* improve cross-company information flow processes and thus, increases responsiveness and time-related flexibility. Cross-company I&C systems and online data provision affect the availability of information and thus, positively influence the responsiveness of the involved actors. Thus, the usage of online and joint planning and control systems and the specific technologies are the basis for the flexibility of transport services and thus, flexibility of the SC.

The measures of the category '*workflow / activity structure*' positively and negatively affect SCP requirements regarding flexibility. *Online and EDI* accelerate communication processes and thus, increase flexibility. *New and standardised material flow technologies* are faster and thus, affect the flexibility of processes. Nevertheless, the higher the level of automation the more goods can be operated, the more the flexibility of the specific system is restricted. The introduction of principles of the Toyota Production System or further 'lean' logistics concepts may accelerate material flow for improved costs, but reduces the flexibility of the system (cf. section 3.1).

Cross-company '*organisational activities*' increase the flexibility of cross-company material and information flow processes. The availability of operational cross-company activities, such as the integration of functional teams and key account managers, increases the knowledge of mutual processes and thus, flexibility. Strategic organisational measures can influence flexibility positively and negatively. Depending on the specific framework conditions, M&A activities and the creation of joint ventures may change the SC structure and this may influence the space and time-related flexibility dimension.

Planning and control systems and approaches allow for the flexible planning of arri-

val times and schedules and thus, improve capacity utilisation.

Product and load carrier design can influence flexibility regarding transport quantities. Table 4 - 13 summarises the considerations of the impact of integrative measures and instruments on flexibility-related SCP requirements.


reading direction  SCP requirements	Impact of integrative measures and instruments on														
	I&C facility structure				workflow / activity structure					organisa-tional structure		planning and con-trol methods			product flow facility structure
	1	2	3	4	1	2	3	4	5	1	2	1	2	3	
flexibility	+				+/-					+/-		+			+
time	+	+	o	o	+	+/-	+/-	+	o	+	+/-	+	+	o	+
quantity	o	o	o	o	o	+/-	+/-	+	o	o	o	+	+	o	+
space	o	o	o	o	o	o	o	o	o	o	+	o	o	o	o

Table 4 - 13: Impact of integrative measures and instruments on flexibility related SCP requirements. (+ positive impact; - negative impact; +/- negative or positive impact to be weighed up (depending on framework conditions); o no relevant impact; () indirect impact)

Impact of Integrative Measures and Instruments on Reliability

The performance dimension of reliability is positively influenced by the usage of latest, standardised, appropriate and proved planning and control methods based on *I&C technologies*. The availability of cross-company information because of joint I&C systems especially improves adherence to schedules. Increasingly auto ID technologies are applied to automated data gathering and processing. Often, auto ID systems are coupled with temperature sensors or location technologies and thus, reliability in terms of quality can be positively influenced.²⁹

Furthermore, adaptations in the '*workflow and activity structure*' can make material and information flows more reliable and stable. New but already standardised technologies can be assumed to be reliable and thus, improve reliability in terms of adherence of schedules as well as good quality. The introduction of quality standards is the central factor to ensure a high and cross-company level of good quality.

The choice of suitable planning, control and monitoring systems and approaches can improve adherence to schedules using sophisticated forecasting techniques. The usage of modelling and simulation techniques allows prior 'testing' of processes and thus, certain disturbance factors and problems can be forecasted and avoided.

Adaptations regarding product or load carrier design are central for the reliability of

²⁹ cf. Amador et al. (2010); López (2011); Makinwa (2010); Yang et al. (2010).

good quality. Table 4 - 14 summarises the considerations of the impact of integrative measures and instruments on reliability-related SCP requirements.


reading direction  SCP requirements		Impact of integrative measures and instruments on														
		I&C facility structure				workflow / activity structure					organisa-tional structure		planning and con-trol methods			product flow facility structure
		1	2	3	4	1	2	3	4	5	1	2	1	2	3	
reliability		+				+					o		+			+
	adherence to schedules	+	+	o	o	+	+	+	+	o	o		+	+	+	+
	quality	o	o	+	o	+	+	+	+	o			o	o	o	o

Table 4 - 14: Impact of integrative measures and instruments on reliability related SCP requirements. (+ positive impact; - negative impact; +/- negative or positive impact to be weighed up (depending on framework conditions); o no relevant impact; () indirect impact)

The discussion of integrative measures and instruments is joined with the conceptual research framework in the following section.

4.4 Intermediate Findings

Chapter 4 applies configuration theory to develop a conceptual research framework and propositions on the performance-oriented integration of CT into SC concepts. Furthermore, the cause-and-effects between the SC and CT concept elements are specified. The measures and instruments for the integration of material and information flows identified in section 2.1.6 are discussed with regard to the applicability to the problem of CT integration and the effect on the specific SCP requirements.

Practical Recommendations on the Usage of Integrative Measures and Instruments

The results of chapter 4 serve as practical recommendations of the performance-oriented integration of CT into SC concepts. The developed framework and underlying assumptions, propositions and cause-and-effect relationships deliver advice for practical application regarding the choice of a suitable CT concept, of adaptation points and for the usage of integrative measures and instruments. A process for the successful integration of CT into SC concepts with a focus on technical and organisational aspects is also provided.

Table 4 - 15 provides practical guidance for the identification of suitable CT concepts depending on the SC strategy and the desired integration point.

Integration point	I	II	III	IV
SC strategy	supplier - manufacturer	manufacturer-store	manufacturer - DC	DC - store
lean I (plan and optimize)	A, C	(A), (B), C	A, C	A, (B)
lean II (continuous replenishment)	A	-	A	A
leagile I (manufacturing postponement)	A	-	B, C	-
leagile II (logistics postponement)	A	-	B	-
agile	(B)	(C)	(B), (C)	-

Table 4 - 15: Applicability of CT types according to SC strategy and integration point.

A = line trains – regular booking; B = line trains - flexible booking; C = CT network

Based on this prior choice of a generally suitable CT concept, the conceptual framework suggests the development of a so-called SCP requirements profile of the SC concept at the specific integration point as well as a performance profile of the corresponding CT concept. The section provides guidance for the comparison of requirements and performance profiles and presents a selection of theoretically derived adaptation approaches.

Table 4 - 16 summarises the findings in an overview table. The summary shows that especially the time dimension can be positively influenced by the application of integrative instruments and measures. Only organisational instruments and measures can affect the SCP requirements of the space dimension. Adaptations to the product flow facility structure positively influence requirements regarding shipment size and transport quantity. Furthermore, this type of integrative measure influences the requirements regarding product type. Adaptations in the workflow activity structure can also be applied here. The influence of integrative measures on the cost dimension has to be evaluated from both a short-term and a long-term view. In particular, integrative measures regarding the applied I&C structure, the utilised planning and control methods as well as the workflow structure impact the cost dimension. Flexibility and reliability can be positively influenced by measures of all categories. However, integrative measures of the organisational structure may cause additional costs, which have to be taken into consideration.


reading direction  SCP requirements	impact of integrative measures and instruments on				
	I&C facility structure	workflow / activity structure	organisational structure	planning and control methods	product flow facility structure
time	+	+	+	+	+
space	o	o	+	o	o
shipment size / transport quantity	o	o	o	(+)	+
product type	o	+	o	o	+
cost	+/-	+	-	+/-	+/-
flexibility	+	+/-	+/-	+	+
reliability	+	+	o	+	+

Table 4 - 16: Summary - impact of integrative measures and instruments on SCP requirements.
(+ positive impact; - negative impact; +/- negative or positive impact to be weighed up (depending on framework conditions); o no relevant impact; (indirect impact))

The developed conceptual framework, propositions and more specific cause-and-effect relationships must be empirically validated. Therewith, chapter 4 serves as the basis for the simulation study presented in chapter 5. The deeper evaluation of a lean SC concept and a CT concept with line transport and regular booking serves to validate and concretise the conceptual research framework presented in this chapter.

5 Performance-oriented Integration of Combined Line Transport into a Lean SC - A Simulation Study

According to McKelvey (1999), modelling and simulation can be understood as the primary scientific process if the given research problem is too complex or too cost-intensive for empirical observation or the application of mathematical modelling approaches.¹ In SCM, empirical research requires the observation and survey of all SC actors that are relevant to the given problem formulation. However, this requires the interruption of daily operations and material flow processes and is thus, often not possible.² Mathematical modelling approaches are usually restricted to dyadical relationships, for instance, between buyer and supplier or shipper and carrier. With every actor included in a mathematical model the complexity rises and thus, several assumptions are necessary.³ Thus, mathematical modelling seems to be insufficient for the analysis of the integration of CT into SC concepts. Simulation methodology is chosen for the in-depth analysis of the performance-oriented integration of CT into SC concepts for the thesis in hand.

The fifth chapter aims at the specification and validation of the chosen aspects of the conceptual model using a simulation study. Therefore, the problem formulation is specified to the analysis of a lean SC concept and a combined CT concept with regular line trains.⁴ First, the research design of the simulation study is introduced. The suitability of the simulation method for the given research problem, central quality criteria and restrictions of the chosen methodology are discussed. Furthermore, the choice of a specific simulation approach and a simulation tool are described (section 5.1). Second, the development of the simulation model of the distribution network of a Swiss retailer is described (section 5.2). This includes the introduction of the simulation-specific problem and target definition (section 5.3), the data gathering and editing process (section 5.4), the development, validation and verification of the simulation model (section 5.5), the development of the experimental plan and setup of experiments (section 5.6) and the discussion of simulation runs and results (section 5.7). Section 5.8 joins the

¹ cf. McKelvey (1999).

² cf. Ibid. There are few publications on experiments; these are usually focused on human behaviour in SCM.

³ cf. Grössler et al. (2005), p. 446.

⁴ The different CT types are introduced in section 3.4.

intermediate results with the findings from the previous chapters to formulate first practical recommendations for the performance-oriented integration of CT into SC concepts.

5.1 Research Design for the Simulation Study

This section gives an overview of the research design for the simulation study and points out the suitability of the approach for the given problem formulation. In a first step, the simulation methodology is classified in terms of research philosophy. In the second step, the advantages and restrictions of the simulation methodology are discussed. In this context, the general application fields for the simulation methodology are introduced. In the third step, different classification approaches and types of simulation models are discussed. This serves as the basis for the concluding choice of a suitable simulation approach and tool for the given problem formulation.

5.1.1 Scientific-theoretical Positioning of the Simulation Methodology

Simulation means conducting experiments with a model of a dynamic system. The simulation model is usually simplified and more abstract than is the real system, but it reflects the central characteristics of the system. The simulation allows the observation of system behaviour over time.⁵

According to Axelrod (2005), '*simulation is a third way of doing science*' (Axelrod (2005), p. 5). Inductive research approaches aim at the discovery of patterns of empirical data, whereas deductive research approaches aim at the development of assumptions and proving them. A simulation builds on specific assumptions as deductive research does. However, it does not prove these. A simulation creates data to be analysed that can be inductively compared with real life data.⁶ The generated data are not empirically gained, but rather they depend on the assumptions and rules of the simulation.⁷ Thus, it does not aim at the identification of patterns in these data (as induction does) and does not aim at the development of assumptions, but focuses on the analysis of the consequences caused by the assumptions made. Axelrod (2005) stated that simu-

⁵ cf. Zeigler (1984).

⁶ cf. Gilbert et al. (1999), p. 16.

⁷ cf. Axelrod (1997a).

lations can be understood as *'thought experiments'* (Axelrod (2005), p. 5).⁸

Usually, the simulation is based on a model derived from theory and transferred to an executable simulation model.⁹ But simulations can also contribute to theory testing and development. Following Hannerman (1995), simulations *'provide an explicit and systematic way of deducing the implications of a theory as it operates under particular circumstances to make predictions about outcomes over time.'* (Hannerman (1995), p. 460).

The simulation methodology has several advantages and application fields for application in the field of SCM and CT. However, the following section introduces the restrictions of the simulation methodology that have to be taken into consideration.

5.1.2 Advantages, Restrictions and Application Fields of Simulation Methodology

This section clarifies the advantages and restrictions as well as the application fields of the simulation methodology. These considerations are the basis for the choice of the simulation methodology in general and the specific simulation approach.

Simulation can be understood as the *'middle way'* between formal modelling approaches and empirical methods, such as experiments and observations. The simulation offers, as experiments do, possibilities to examine the effect of altering one variable while holding all other variables constant.¹⁰ In general, there is better control over the experimental framework parameters.¹¹ Simulation models are formally defined. Nevertheless, no specific mathematical formulations are necessary for the analytical solving of the given problem formulation.¹² Furthermore, a simulation allows the analysis of a SC for a long time span in a compressed time.¹³

Thus, simulation can support the planning of non-existent systems. Visualisation often supports the analysis of complex cause-and-effect relationships. Often, the usage of simulation studies reduces planning costs and reveals cost risks.¹⁴

⁸ cf. Axelrod (2005), p. 5.

⁹ Simulation involves constructing a testable model and the development process generally proceeds from theory to model to simulation. cf. Hannerman (1995), p. 458.

¹⁰ cf. Ibid., p. 459.

¹¹ cf. Axelrod (2005), p. 8.

¹² cf. Kuhn et al. (1998), pp. 1.

¹³ cf. Kot et al. (2009).

¹⁴ cf. Kuhn et al. (1998), pp. 1.

A 'trial-and-error' process is not advisable in the context of SCM and investment-intensive CT.¹⁵ Simulation methodology, in particular, allows the analysis of cause-and-effect relationships and thus, of dynamic SC behaviour. It allows the systematic investigation of interdependencies between the elements of SC and CT concepts and the identification and quantification of cause-and-effect relationships.

Simulation methodology is a suitable methodology for the description and exploration of complex systems.¹⁶ Axelrod (1997)¹⁷ and (2005)¹⁸ analysed the advantages of simulation more in detail, identifying seven application fields: (1) *prediction*, (2) *performance*, (3) *entertainment*, (4) *training*, (5) *education*, (6) *proof* and (7) *discovery*.

(1) *Prediction*: Simulations can be used to calculate complex input data. These data are processed by means of hypothesised mechanisms to generate predictions about the consequences. These results can, for instance, be used to develop or refine a theory.¹⁹

(2) *Performance*: In particular, in the field of artificial intelligence simulations are used to accomplish specific tasks. Axelrod (2005) introduced medical diagnosis, speech recognition and function optimisation as examples. Artificial intelligence can be understood as the simulation of human decision making, perception or interaction.²⁰

(3) *Training*: There are several approaches of simulation systems for training purpose. Simulations train people by the provision of a dynamic, interactive and accurate environment (e.g., flight simulators).

(4) *Entertainment*: Some training applications are enhanced for entertainment purposes. Today, a number of simulations have complete imaginary worlds available in the computer games market.

(5) *Education*: The education function of simulation is closely related to training and entertainment. Axelrod (2005) introduced the computer game 'SimCity',²¹ which enables players to experiment with variables in a hypothetical city (e.g., tax rates). The education effect lies in users' ability to transfer relationships and principles to their real lives.²²

¹⁵ cf. Grössler et al. (2005), p. 447.

¹⁶ cf. Hannerman et al. (1997).

¹⁷ cf. Axelrod (1997a).

¹⁸ cf. Axelrod (2005).

¹⁹ For instance the 'digital factory'. For details see for instance Bracht et al. (2011), Kühn (2006).

²⁰ cf. Axelrod (2005), p. 3.

²¹ See for instance www.simcity.ea.com.

²² cf. Axelrod (2005).

(6) *Proof*: Simulations can serve to provide proof for existence in general.²³ Axelrod (2005) referred to the so-called ‘*Conway’s Game of Life*’ published by Poundstone (1985), which demonstrates that extremely complex behaviour can result from very simple rules.²⁴

(7) *Discovery*: Simulation can support the validation or improvement of the model it is based on. The simulation helps discover relationships between the model’s elements. According to Axelrod (2005), it can be assumed that ‘[...]the simpler the model, the easier it may be to discover and understand the subtle effects of its hypothesized mechanisms’ (Axelrod (2005), p. 4).²⁵

As a scientific methodology, a simulation’s value lies in the functions of prediction, proof and discovery.²⁶ Thus, for the given research problem a simulation can support the discovery of cause-and-effect relationships between the elements of SC and CT concepts. Furthermore, simulation can be used to predict system behaviour depending on different SC concept adaptations and can thus, support the validation and refinement of the conceptual research model presented in chapter 4.

Restrictions of Simulation Methodology

Despite the advantages of simulation methodology, there are restrictions that have to be considered when applying it.

Often simulation is misunderstood as an optimisation approach.²⁷ Although simulation results can serve as the basis of an iterative optimisation process, this does not necessarily lead to the optimal configuration of a system. Several simulation tools support the searching process for the optimal system configuration and provide enhancement modules for the optimisation of existing models.

Simulation models have subjective characters. They depend on the modelling person. The setup of a simulation can be characterised by the simplification of a given real life situation and is thus, subjective (as classical modelling). Furthermore, the quality of the simulation model depends on the simulation technique, experience, skills and creativity of the modelling person.²⁸ The simulation must also be at a suitable abstraction

²³

cf. Ibid.

²⁴

cf. Poundstone (1985).

²⁵

cf. Axelrod (2005).

²⁶

cf. Ibid.

²⁷

cf. Ibid.

²⁸

cf. Rabe et al. (2008), pp. 23.

level. It must be avoided that the model is oversimplified and thus, leads to non-resilient results.²⁹

The accomplishment of the simulation study, including data gathering and editing, model building and evaluating the simulation results, can be time consuming and cost-intensive. Thus, benefit and effort must be balanced.³⁰

The results of a simulation study are based on simplified assumptions made to reduce the complexity of the model and to reduce the simulation time. Detailed results can give a false understanding of the accuracy level of the simulation results. Thus, the generalisability of the results is restricted and this must always be considered with regard to the made assumptions.³¹ This simplification of reality negatively affects the accuracy of the simulation results. Thus, the model provides results only for the given context for the transfer to reality. For other parameters, the simulations might not be valid. Thus, the validation of the model is critical for a resilient simulation.

This discussion of the restrictions and disadvantages of the simulation methodology proves the importance of the validation and verification steps as well as sensitivity analyses of the developed model.

The following section introduces specific criteria for the evaluation of simulation studies.

5.1.3 Quality Criteria for Simulation Studies

To derive reliable statements from a simulation the specific quality criteria of the model and development process must be considered. These criteria result from the scientific-theoretical positioning and the application orientation of the thesis in hand (cf. section 1.2).³²

The underlying problem formulation and the purpose of the simulation are central to the design of the choice of simulation approach and tool, level of detail and included variables. However, independent quality criteria are suitable for all types of simulations. These quality criteria correspond to the classical research quality criteria, but extend and

²⁹ cf. Craig (2011).
³⁰ cf. Kuhn et al. (1998).
³¹ cf. Craig (2011).
³² cf. Gilbert et al. (1999).

interpret these for the field of simulation.³³ The simulation study must meet the targets of (1) *internal and external validity*, (2) *usability*, (3) *extendibility* and (4) *replication*.³⁴

'*Validity*' means the correct implementation of the model in the simulation tool. '*Internal validity*' stands for the accurateness of the programming of the model itself. This is sometimes difficult to achieve, for example an unexpected simulation result may be caused by a programming mistake or it may be a surprising consequence of the model itself.³⁵ '*External validity*' means the correct modelling of reality. This encompasses the correctness of model assumptions, postulated framework conditions and the empirical valid modelling of the simulation object.³⁶ In this context, the '*sensitivity*' addresses the applicability of the simulation model for changing initial situations and parameters.³⁷ This is vital especially if comparisons of different initial parameters are to be analysed. The simulation model should be robust regarding differentiations. This aspect must be proven in a verification and validation phase including a sensitivity analysis. For instance, Rabe et al. (2008) presented a number of different validation and verification techniques for simulation studies.³⁸

'*Usability*' means that the researcher as well as all other users and readers are able to follow and understand the structure and functioning of the model as well as the programming and interpretation of the simulation results.³⁹

'*Extendibility*' means that the simulation can be adapted for further use and other users. During the development and documentation of the model, this aspect must be considered. Extendibility is closely related with ability for replication.⁴⁰

'*Replication*' confirms whether the claimed results of a given simulation are reliable in terms of reproduction. This confirmation is necessary to avoid the publication of results based on programming errors, misrepresentation and analysing errors.⁴¹

³³ See for instance Albers et al. (2007), pp. 33; Lamnek (2005), pp. 118; Lienert et al. (1998), pp. 7.

³⁴ cf. Axelrod (1997a), p. 7.

³⁵ cf. Axelrod (2005), p. 7; Axelrod (1997b).

³⁶ cf. Rabe et al. (2008), pp. 15.

³⁷ cf. Ibid., p. 16; Scharkow (2004), p. 7.

³⁸ cf. Rabe et al. (2008), pp. 93.

³⁹ cf. Axelrod (2005); Wenzel et al. (2008).

⁴⁰ cf. Axelrod (2005); Scharkow (2004), p. 7; Wenzel et al. (2008).

⁴¹ cf. Scharkow (2004), p. 7.

The *'kiss' principle* (*'Keep it simple, stupid!*) is a recommended approach to reach the stated quality criteria.⁴² The principle considers that researchers and the general audience have limited cognitive ability. If there is a surprising result, it is helpful to be confident that everything in the model can be tracked. Simplicity allows other researchers the chance to replicate the model and to extend it in other directions.⁴³

5.1.4 Structure and Classification of Simulation Models

This section introduces different classification approaches for simulations as the basis for the choice of a specific simulation approach and tool in section 5.1.5.

A simulation model usually consists of simulated units as well as objects and transition rules. Depending on the given application field, simulation units can be variables, objects, cells or agents. The transition rules describe how the simulation units change over time. The simulated units and rules can be depicted using different simulation approaches. The choice of suitable simulation approaches depends on the specific target of the simulation and the necessary level of abstraction.⁴⁴

Continuous vs. Discrete Simulation Models

Simulation time can be either continuous by proceeding in discrete time intervals or discrete and event-based.⁴⁵ In a *continuous simulation*, variables change in arbitrary small time steps. The mathematical basis of continuous models are (non-linear) differential equation systems. These can be solved by numerical integration. *Discrete models* are restricted to discrete time steps with discrete value changes of the state variables. A phase-based discrete simulation time proceeds in a defined step width. This is suitable for online observations of the simulation since simulation time usually has a defined relation to actual time. Modelling is comparably easy, but simulation time might be wasted if many simulated variables are inactive for a longer time. An *event-based simulation* has flexible time steps based on the appearance of events.⁴⁶ Simulated units are only active if they are activated by an event. After the reaction of an event and the passing of the effect, the current time is set on the time point of the next event. The

⁴² cf. Axelrod (1997a).

⁴³ cf. Ibid.; Axelrod (1997b); Axelrod (2000).

⁴⁴ cf. Herrler (2007).

⁴⁵ cf. Ibid.; Troitzsch (2004).

⁴⁶ cf. Brade (2003); Kuhn et al. (1998); Stefanovic et al. (2009).

main disadvantage is the elaborative handling of the event list since the simulation time includes time jumps.⁴⁷ For the model building for discrete event simulations, standardised elements, such as random numbers, queuing lines and probability distributions, can be used. Furthermore, petri net theory can be applied to the development of discrete event simulation models.⁴⁸

Furthermore, so-called macro and agent-based simulations can be distinguished. Macro simulations are based on sets of differential equations or system dynamics. System dynamics simulations are usually applied to macro policy-type problems.⁴⁹ In an agent-based simulation, the population variables and other state variables are replaced by the simulation of the behaviour and interaction of the single objects.⁵⁰

Deterministic, Stochastic and Interactive Simulation Models

Simulation models can be distinguished with regard to the type of variables used. In a *deterministic simulation model*, all environmental factors and the behaviour of the model must be clearly determined. The real system is modelled without coincidence parameters and according to clear rules. Thus, each simulation run leads to identical results.

However, a simulation model can include *stochastic and interactive elements*. A simulation model is stochastic if its behaviour is determined by one or more random variables. Models are dynamic to the extent that time is an overarching component of the model and its corresponding behaviour.⁵¹

Probability distributions can be understood as abstraction elements. Instead of stable cause-and-effect relationships, probability distributions derived from reality can be used for the simulation model.⁵² If stochastic elements are included in the simulation model, the results of the simulation run are not determined. Thus, it is necessary to accomplish a series of simulation runs to get convincing results.⁵³

⁴⁷ cf. Brade (2003).

⁴⁸ cf. Hung et al. (2006); Biswas et al. (2004)

⁴⁹ For details on system dynamics applications in the field of SCM see Forrester (1995); Georgiadis et al. (2005); Holmes (1991); Lane (1999).

⁵⁰ For details on agent-based simulation in the field of SCM see Chang et al. (2001); Herrler (2007); Kuhn et al. (1998); Lättilä et al. (2010); Troitzsch (2004).

⁵¹ cf. Dooley (2002).

⁵² cf. Troitzsch (2004).

⁵³ In 2010 Owen published a literature review on the usage of different simulation methods in the field of SCM.

5.1.5 Application Fields of the Simulation Methodology in Transport and SCM Science

Simulation has become an important approach for decision support in the field of SCM. In practice, especially in the field of production, it has been applied for the validation of new layout choices,⁵⁴ capacity planning and the evaluation of PPC approaches (shop floor planning, PPC, (dynamic) scheduling of the production orders, capacity plans and labour allocation).⁵⁵ Lately, several other application fields, e.g., SC planning, product development and design and marketing, have risen to prominence.⁵⁶

According to Goldsim (2011), four decision support situations for simulation models in SCM can be distinguished: (1) optimisation problems, (2) decision analysis, (3) diagnostic evaluations and (4) risk management.

A simulation for (1) *optimisation purposes* aims at finding the optimal guidelines to either maximize or minimize a certain result by means of iterative improvements, e.g., the optimal inventory level, an allocation of DCs and stores or the machine order planning. A simulation for (2) *decision analysis* is a quantitative comparison of two or more given alternatives, e.g., the simulation-based analysis of the performance effect of the SC caused by different location alternatives for a new factory. (3) *Diagnostic evaluations* can be used to identify problems with an unknown cause. The SC simulation improves the understanding of cause-and-effect relationships and allows the evaluation of different solution possibilities. Simulation supports (4) *SC risk management* in order to avoid unexpected disruptive events, e.g., the disruptions of material flow and to evaluate risk impacts such as fire, floods or labour strikes. This can help anticipate risk and develop suitable mitigation plans.⁵⁷ Changes in one segment of a SC can cause short-term and long-term effects on SCP. To avoid unexpected disruptions, e.g., the effects of outsourcing particular processes, building new factories or switching suppliers can be anticipated. Thus, in contrast to decision analysis, simulation is used to support the implementation of the project in order to reduce costs, meet schedules and minimize risks.⁵⁸

⁵⁴ cf. Kuhn et al. (1998); Kühn (2006); Rabe et al. (2008).

⁵⁵ cf. Kosturiak et al. (1999).

⁵⁶ cf. Ibid.

⁵⁷ cf. Goldsim (2007), pp. 6.

⁵⁸ cf. Ibid., p. 7.

Terzi et al. (2004) conducted a literature review on the application fields of the simulation methodology in SCM.⁵⁹ The authors distinguished between the different objectives of simulation studies (e.g., strategic, tactical or operative), different simulation approaches (simulation tools and languages) and different development stages of the models (conceptual models to commercial applications).⁶⁰

According to Terzi et al. (2004), the two main objectives for the use of simulation models in the field of SCM and transport are network design and strategic decision support.⁶¹ Network design includes the determination of nodes in the network as well as the design of the connections between these.⁶² Strategic decision support can mean the evaluation of the suitability of strategies and concepts, such as quick response, CPFR or outsourcing to third parties.⁶³

A simulation methodology can be applied to all central process types in SCM. Following the classification of APS systems, simulations can be applied to demand and sales planning, SC planning, supply and distribution channel configuration, location of stocks, selection of suppliers and partners,⁶⁴ inventory planning over multiple stages, distribution and transportation planning⁶⁵ and production planning and scheduling.⁶⁶

Furthermore, simulation models have been applied to specific problems, such as the investigation of the effects of uncertainty,⁶⁷ different order release mechanisms,⁶⁸ partial shipments⁶⁹ specific handling efforts and different inventory policies,⁷⁰ and the impact of transshipments on service levels and costs.⁷¹ Disney and Towill (2002), for instance, analysed the configuration of VMI approaches,⁷² including transport processes.⁷³

⁵⁹ cf. Terzi et al. (2004).

⁶⁰ cf. Ibid., p. 10.

⁶¹ cf. Owen (2010).

⁶² cf. Terzi et al. (2004), pp. 23.

⁶³ cf. Ibid., pp. 25.

⁶⁴ cf. Kosturiak et al. (1999); Schunk (2000); Stadtler (2005); Stadtler et al. (2000).

⁶⁵ cf. Bagchi et al. (1998).

⁶⁶ cf. Ibid.; Biswas et al. (2004); Chan et al. (2011); Chatfield et al. (2009); Goldsim (2007); Kot et al. (2009); Owen (2010); Rodriguez-Rodriguez et al. (2011); Stefanovic et al. (2009); Sen et al. (2004); Schunk (2000); Thron et al. (2006); Thron et al. (2007); Yang et al. (2009).

⁶⁷ cf. Petrovic (2001).

⁶⁸ cf. Chan et al. (2001); Chan et al. (2002).

⁶⁹ cf. Banerjee et al. (2001).

⁷⁰ cf. Towill (1996); Disney et al. (1997).

⁷¹ cf. Banerjee et al. (2003); Hong-Minh et al. (2000).

⁷² cf. Disney et al. (2002).

⁷³ cf. Disney et al. (2003).

Furthermore, there is a number of applications of simulation methodology in the field of CT. This includes the evaluation of transport and terminal logistics,⁷⁴ the usage of optimisation methods, vehicle planning, stowage planning, capacity planning for cranes and overheads, storage and stacking logistics, transport optimisation, crane transport optimisation and rail terminals.⁷⁵

In general, simulations support strategic, tactical and operational activities. There are several publications on the choice of different terminal layouts and used handling equipment regarding efficiency and cost (strategic).⁷⁶ Terminal logistics and optimisation methods for CT are another application field for simulation. In particular, for large terminals the simulation technique has gained much interest (operational).⁷⁷ The analysis of process alternatives, for instance in the case of disturbances, is a rather tactical application field.⁷⁸

According to the findings on the advantages and application fields of the simulation method, the following section addresses the applicability of the simulation methodology to the given research problem.

5.1.6 Discrete Event Simulation as the Research Methodology for the Analysis of Performance-oriented Integration of CT into SC Concepts

Simulation is chosen as the research methodology for the problem of the performance-oriented integration of CT into SC concepts. The simulation methodology supports the validation and concretisation of the conceptual model on the integration of CT into SC concepts. Since the technical and organisational elements of SC and CT concepts are central for the thesis in hand, an object-oriented simulation approach is chosen.

This simulation methodology allows analysing the performance effect of CT integration. The simulation methodology is able to deal with:

- (1) The high complexity and multiplicity of variables and
- (2) Non-linear and time-delayed cause-and-effect relationships between variables.

⁷⁴ cf. Ballis et al. (2004); Dessouky et al. (1995); Ferreira et al. (1993); Hartmann (2004); Klima et al. (1996); Liu et al. (2002); Longo (2010); Ramirez-Marquez et al. (2008).

⁷⁵ cf. Longo (2010); Rizzoli et al. (2002); Ramirez-Marquez et al. (2008); Steenken et al. (2004).

⁷⁶ cf. Abacoumkin et al. (2004). Ballis et al. (2004); Ballis et al. (2002); Longo (2010); Ramirez-Marquez et al. (2008); Rizzoli et al. (2002).

⁷⁷ cf. Gambardella et al. (1998), Rizzoli et al. (2002); Liu et al. (2002); Nam et al. (2002).

⁷⁸ cf. Hartmann (2004); Shabayek et al. (2002).

Furthermore, real experiments in the SC context can be avoided. Thus, the simulation methodology allows the validation and specification of the conceptual research framework introduced in the previous section. In particular, the simulation can predict, prove and discover (cf. section 5.1.2), which is central for the identification of additional relevant cause-and-effect relationships between the elements of SC and CT concepts. It can also analyse the performance effects of the integration of CT into SC concepts and exam the impact of adaptations the SC concept to improve the fit between SC and CT concepts.

Following Chang and Makatsoris (2001), the application of a discrete event simulation approach allows the evaluation of SCP before and after the integration of CT.⁷⁹ It allows in particular what-if analysis to improve the planning basis and the comparison of operational alternatives without the interruption of the running SC and thus, contracts the time for decision processes.

There is a variety of tools offered by different providers and available for the purpose of simulation, e.g., eMplant, Arena, Witness or Quest. Furthermore, object-oriented programming languages such as C++, UML, swarm or Java can be applied.⁸⁰ For the choice of the simulation tool in the thesis in hand, the following two aspects are critical:

(1) *The possibility to address discrete events:* SCs are significantly influenced by random, discrete events (e.g., the disruptions in supply caused by strikes or congestion). The ability of the simulation software to represent these events is important for the evaluation of flexibility, robustness and overall performance.

(2) *The capability to link an external database:* The performance-oriented simulation of CT integration into SC concepts requires information on current inventories, order rates and arrival times. Owing to the large amount of data on the orders, route plans and transport schedules, transport and handling times, transport distances, store opening times and delivery windows, the entering of data by hand into the simulation tool is time-consuming. Thus, the simulation tool must provide an interface to a database system including the relevant input data as well as to document the history data of the simulation runs.

⁷⁹ cf. Chang et al. (2001).

⁸⁰ cf. Scholz-Reiter et al. (2008), p. 121.

The simulation tool used for the thesis in hand is the software '*Flexsim*'.⁸¹ Flexsim is an object-oriented simulation tool based on simulation modules that can be customised according to the specific application field. Flexsim provides a clearly arranged graphical user interface. Furthermore, an integrated 2D and 3D virtual reality animation is included that can display processes in real time.

Flexsim is based on a C++ compiler and FlexScript (a C++ function library) for model development. Thus, all C++ libraries and functions can be utilised.⁸² It is possible to link Flexsim with any ODBC⁸³ database (e.g., Oracle, Access) and data structures (e.g., text files, MS Excel and MS Word files). Furthermore, there are specific applications offered by Flexsim for manufacturing and material handling systems, as well as the simulation of semiconductor fabs and tools, marine container terminals, hospitals and network storage systems.⁸⁴

As a result, Flexsim is chosen as a suitable instrument for the modelling and simulation of the integration of CT into a lean SC. In particular, the object and discrete event orientation and the possibility to link the tool with external databases for input and output data are central decision parameters.

5.2 Process Model for the Simulation Model Development

This section introduces the procedure for the development of the simulation model and the accomplishment and analyses of simulation runs.

The simulation study in the thesis in hand follows a five-step approach following the considerations of Rabe et al. (2008)⁸⁵ and Wenzel et al. (2008).⁸⁶ In the following section, the five steps are briefly introduced.

Step 1: Problem Formulation and Target Definition

The first step includes the specification of the problem formulation and the definition of targets for the simulation study. The phase includes the definition of the quality criteria for the simulation and of the used terminology.⁸⁷

⁸¹ For further details on the simulation software see <http://www.flexsim.de/>.

⁸² Additional applications such as ExpertFit®, OptQuest® and Visio® can be compiled into the application. cf. Flexsim (2011)

⁸³ ODBC = open database connectivity

⁸⁴ cf. Diamond et al. (2002). The as-is analysis is independent of the simulation tool or language.

⁸⁵ cf. Rabe et al. (2008).

⁸⁶ cf. Wenzel et al. (2008), p. 109.

⁸⁷ cf. Ibid., pp. 114.

Step 2: Data Gathering and Editing for Model Configuration and Validation

The second step encompasses the gathering of all relevant data for the simulation study as well as data editing for further processing in the case of data shortages or abundance. Furthermore, the second step includes the testing and definition of probability distributions for the stochastic variables in the simulation model.⁸⁸

Step 3: Development, Validation and Verification of the Simulation Model

The third step involves building the conceptual model, formalised model and simulation model.⁸⁹ Therefore, the SC and CT concepts are analysed, modelled, formalised and finally implemented. Several verification and validation steps ensure the compliance of the developed models with the as-is situation (external validity), the functioning of the model (internal validity) and suitability for the defined research target. A sensitivity analysis makes sure that the model is also valid for a defined range of different input and output parameters.

Step 4: Experimental Plan and Setup of Experiments

The quality of a simulation can be increased by the usage of a predefined experimental plan. It avoids that only the simulation results guide the study, but all interesting aspects are analysed in a structured way.⁹⁰ The simulation scenarios are the basis for the definition of specific experiments. Simulation runs are accomplished according to the experimental plan. The length of a simulation run and, if necessary, of a stabilisation phase, the initial values for the variables and objects as well as the number of simulation runs are determined.

Step 5: Description and Analysis of Simulation Results

In the fifth step, simulation results are analysed, depicted and interpreted.⁹¹ The analysis is completed by a discussion of scope, assumptions and simplifications of the simulation study and the transferability and generalisability of findings.

This classification into five steps for the process of a simulation study serves as a structure for the following sections (section 5.3 to section 5.7).

⁸⁸ cf. Ibid., pp. 119.

⁸⁹ This conceptual model must be distinguished from the conceptual research model introduced in section 4.

⁹⁰ cf. Rabe et al. (2008); Wenzel et al. (2008), p. 139.

⁹¹ cf. Wenzel et al. (2008), pp. 139.

5.3 Step 1: Problem Formulation and Target Definition

According to Chang et al. (2011), in the first phase of a SC simulation project an understanding of the overall SC is necessary.⁹² This includes the analyses of industry-specific characteristics (e.g., SC strategy, SC environment, SC actors) and company-specific characteristics, and the description of the empirical database. Furthermore, the choice of specific performance indicators,⁹³ the development of simulation scenarios and the formulation of the expected simulation results are part of the first simulation phase.⁹⁴

5.3.1 Scope and Target Definition

In a first step, the specific problem and target of the simulation study is defined. To specify and validate the conceptual model presented in chapter 4 one aspect of the framework is selected for the simulation study. The simulation focuses on the analysis of a lean SC concept (type II - continuous replenishment) and the performance-oriented integration of a line transport with regular booking. The analysis is concentrated on the integration of CT offers between the manufacturer and the DC/store. Table 5 - 1 visualises this specification.

SC strategy	I - supplier - manufacturer	II - manufacturer - store	III - manufacturer - DC	IV DC - store
lean (type I - plan and optimize)	A, C	(A), (B), C	A, C	A, (B)
lean (type II - continuous replenishment)	A,	-	A	A
leagile (type I - manufacturing postponement)	A	-	B, C	-
leagile (type II - logistics postponement)	A	-	B	-
agile	(B)	(C)	(B), (C)	-

Table 5 - 1: Focus of simulation study. (A – line transport (regular booking), B – line transport (flexible booking), C – CT network; A – suitable, (A) restricted suitable)

⁹² cf. Chang et al. (2001).

⁹³ cf. Ibid.

⁹⁴ cf. Arnold (2010).

The targets of the simulation study are:

- To compare the performance effect of CT integration with unimodal road transport,
- To discuss the performance effect of single adaptations to the SC concept, namely adaptations to the production and distribution concepts and
- To uncover unknown cause-and-effect relationships between the elements of the CT and SC.

Thus, in the following section the empirical database and the specific problem formulation are introduced.

5.3.2 Problem Formulation - Understanding the Initial SC Concept

The empirical data for the simulation study are mainly provided by *Manor*, the biggest Swiss department store owner. *Manor* AG owns 70 (2010) department stores and belongs to the *Manor* Group.⁹⁵ Recently, *Manor* experienced an extension and instability of transport times and thus, a reducing adherence to schedules for store deliveries. These delays were caused by congestion related to infrastructure shortages or weather. Transport political regulations (e.g., night, weekend and inner city bans) restricted transport flexibility as well as the enhancement of transport times. In particular, the sustainability strategy of *Manor* urges the transport division to reduce emissions and to improve *Manor*'s 'green image'.⁹⁶

The simulation model is based on a part of *Manor*'s food and non-food distribution network in Western Switzerland. This part of the model was chosen since *Manor* actually considers CT integration in this region and has already accomplished a pilot project for the delivery of the department store in Geneva. *Manor* provides empirical data and experience about the project for the validation of the simulation study in the thesis in hand. Thus, the simulation results can be complemented by qualitative data.

There are eleven department stores in Western Switzerland. They are located in a circle of approx. 80 km from the CT terminal of *Swiss Post* in Daillens. Non-food products are sent to the stores from the two main DCs in central Switzerland (Möhlin and

⁹⁵ The *Manor* Group also owns FLY and Athleticum, two stores for furniture and sports equipment and fashion. The *Manor* Group belongs to the Maus Frères Holding in Geneva. cf. Manor (2011b); Maus (2011). *Manor* has an annual turnover of 2.987 Bio. CHF (2010) and approximately 11,000 employees. cf. Manor (2011a). *Manor* is the largest department store group in Switzerland and has in this segment a market share of approximately 59%. The biggest competitors are Migros (Globus), Coop City department stores, Jelmoli and Loeb

⁹⁶ cf. Manor (2011c).

Hochdorf). For some deliveries, the shipments of the two DCs are bundled. In this case, the products are transported from Möhlin to Hochdorf by road. Both DCs are close to the CT terminal of *Swiss Post* in Härkingen.

The stores report their sales on a daily basis. They order goods via either next day or same day deliveries. Next day delivery means that the orders must be made by 4:00 PM to be delivered on the next day. The delivery time point depends on the specific opening times of the delivery platform / loading ramp as well as the external restrictions, such as inner city, weekend and night time driving bans.

Manor uses a classification of products according to priority classes. There are priority goods for same or next day delivery. These goods are always transported to the destination, even if an additional transport vehicle is necessary. Non-prioritized goods are seasonal or action goods, which are provided some time in advance to balance transport capacities. This means that the trucks load all prioritized products before loading non-prioritized goods. For non-prioritized products, no additional transport processes are initiated.

Manor accomplishes transport and route planning itself. For transport, *Manor* assigns different road carriers. On a daily basis, these road carriers announce the specific truck characteristics (e.g., ID number, capacity) as the basis for transport and route planning. Transport and route planning are made once for the period January to September and there is a second plan for October to December, reflecting the increase in demand for goods at Christmas. The basis for the thesis in hand is the basic transport and route plan. From October to December, transport quantities are significantly higher. Thus, in accordance with *Manor*, the CT integration for the basic service is evaluated. In practice this can be complemented by additional road or CT for the '*high season*'⁹⁷.

Depending on the product type and quantities, road carriers either deliver the goods in milk runs or via direct transport (cf. section 3.3.3). Furthermore, there is a regional platform in Sion where products from different DCs can be recombined. Figure 5 - 1 provides a schematic overview of the most important sites in the simulation study.

⁹⁷ For the resulting restrictions and generalisability see section 5.7.6.

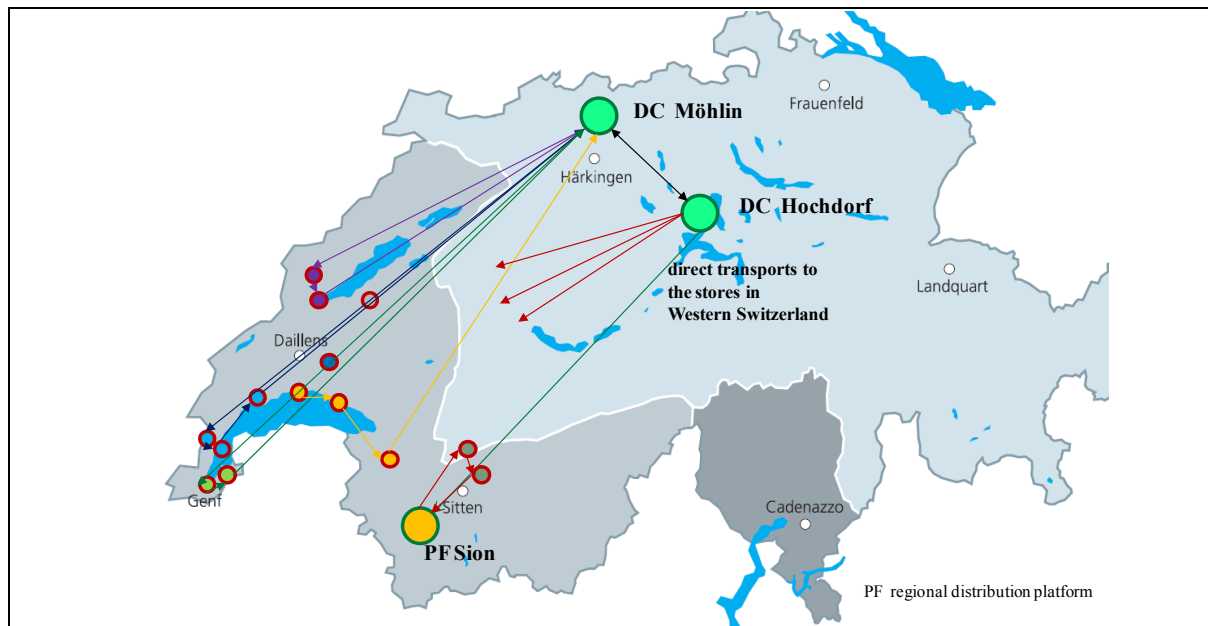


Figure 5 - 1: Schematic of the as-is situation – Manor distribution network (Western Switzerland).⁹⁸

Recently, *Manor* has considered the integration of CT for store deliveries in Western Switzerland. A one-week test run was completed in May 2011 for delivery to stores in Geneva. The simulation study supports the analysis of the CT into SC concepts and allows the firm to identify suitable adaptation approaches to increase SCP.

5.3.3 CT Integration Scenarios

The integration of CT into the SC of *Manor* is supposed to be accomplished over the terminal network of *Swiss Post*.

*Swiss Post*⁹⁹ operates three CT terminals in central (Härkingen), Eastern (Frauenfeld) and Western Switzerland (Dailens) at the three package distribution centres. They are connected by regular line transport.¹⁰⁰ *Swiss Post* offers as CT operator-free capacities on the trains on a regular and flexible basis to shippers. Owing to the advantageous locations of the terminals, the offer of CT services attracts shippers with distributed sites in central Switzerland as well as in Eastern or Western Switzerland. These termi-

⁹⁸ Own illustration.

⁹⁹ *Swiss Post* has its headquarters in Berne is with approximately 42,000 employees (2010). It is thus the second largest employer in Switzerland with a revenue of 7.895 Bio. CHF (2010). *Swiss Post* runs about 2600 stores and transports approximately 3 Bio. shipments, 100 Mio. packages and approximately 100 Mio. passengers. *Swiss Post* runs for the transport of packages three main package DCs. Furthermore, there is quantity of letter DCs and regional letter DCs. Post (2011c). The central letter distribution centres are connected by regular train transports and all their own siding tracks. cf. Post (2011a); Post (2011b).

¹⁰⁰ cf. Post (2011a); Post (2011b).

nals are connected by daily trains by *SBB Cargo*¹⁰¹ and *Railcare*¹⁰². The road carriers *Hugelshofer* and *Dreier* accomplish pre- and ongoing road transport by offering vehicles and driving personnel.¹⁰³ These five companies founded a cooperation to offer CT services to different customers.¹⁰⁴ Each member of the cooperation can act as the central marketing, planning and control company to provide the overhead services to different customers.

The simulation scenario includes modelling the bundling of transport flows for the two DCs and the usage of regular line CT between the CT terminal in Härkingen and Dailens. *Swiss Post* offers line transport for regular and flexible bookings eight times a day in both directions.

The simulation study aims at the analysis of the shift from unimodal road transport to CT for store delivery. The effects on SCP and on the adaptations of the production and distribution concepts to improve integration are examined. Therefore, it is assumed that the transport routes connect the same stores as in the initial situation. Figure 5 - 2 gives a schematic overview of the simulation scenario including CT.

¹⁰¹ *SBB Cargo* is the biggest rail carrier in Switzerland with approximately a 72% market share. For further information see www.sbbcargo.ch.

¹⁰² *Railcare* is a comparably small rail carrier focusing on so-called 'pendel trains' for CT. In 2010 Coop bought *Railcare*. For further information see <http://www.Railcare.ch/> and the presented mini case in section 2.15.

¹⁰³ *Hugelshofer* and *Dreier* are Swiss road carriers and exclusive partners for *Swiss Post* for package deliveries. Furthermore, they are partners for the CT service offered by *Swiss Post*. *Hugelshofer* is located in Frauenfeld and accomplishes the pre- and ongoing haulage in Eastern Switzerland. For detailed information on *Hugelshofer* see Hugelshofer (2011). *Dreier*, located in Suhr, focuses on the transports in Western Switzerland. For detailed information on *Dreier* see Dreier (2011).

¹⁰⁴ cf. Post (2011b), enhanced by expert interviews.

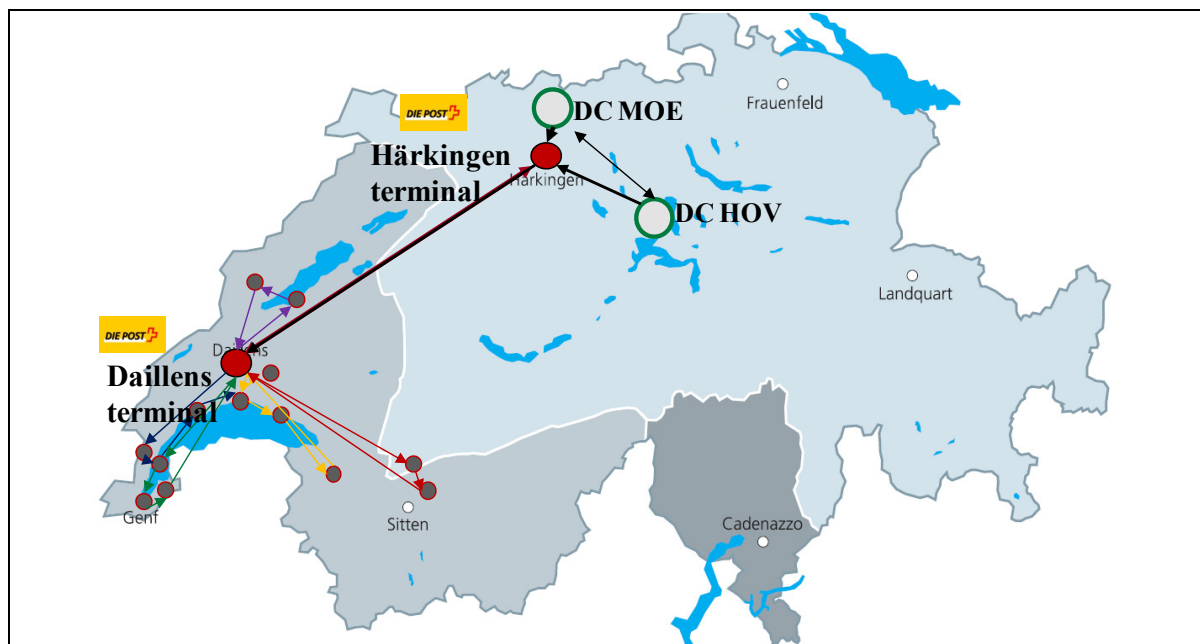


Figure 5 - 2: Schematic scenario – Manor distribution network including CT (Western Switzerland).¹⁰⁵

The expected results are the stabilisation of transport times and improved adherence to schedules for store delivery. Furthermore, total emissions can be reduced because of the better emission balance of rail transport in comparison with unimodal road transport. Additionally, a positive impact on the utilisation and number of transport vehicles is assumed.

Furthermore, in this scenario adaptations to the SC concept, namely the production and distribution concepts, are analysed.

For the discussed scenario of CT integration, the expected results are summarised in the form of hypotheses. However, because simulation does not allow the testing of hypotheses in a classical quantitative way, in the following section the term ‘*scenario*’ is applied to the formulation of expected results. These statements correspond to the different simulation setups and give important hints for the setup of the experimental plan (cf. section 5.6).

¹⁰⁵ Own illustration.

5.3.4 Performance Indicators for the Evaluation of Simulation Scenarios

For the analysis of the developed scenarios, the key figures or performance indicators derived in section 2.3.5 are applied. Performance indicators with a focus on the single order and with a focus on the entire SC concept can be distinguished.

Figure 5 - 3 visualises the performance indicators applied to the simulation study.

Lead time and *adherence to schedules* are evaluated separately for each order and thus, information about the average values of these performance indicators can be gained. The *utilisation of capacities* as well as the *inventory level* are indicators for the evaluation of the performance of the entire system (the specific transport system, production system or the different transport vehicles or production).

Total *lead time* can be calculated by the different lead time parts, such as transport time, handling time, production time, processing time, storage time and waiting time. *Adherence to schedules* means the meeting of delivery windows for loading and unloading of goods. In the centre of interest is here the meeting of the delivery window and the destination store. For the simulation study, 'adherence' is interpreted in two different ways. (1) *Adherence to schedules regarding deviations* means that the delivery neither happens too early nor too late. (2) *Adherence to schedules regarding delays* means that only too late transports are interpreted as non on time. This differentiation was made for two reasons. First, the experts prove that in retail practice temporal buffers are planned to balance unexpected delays. If the transport is too early, the truck driver waits near the destination until the beginning of the delivery window. Second, to improve the generalisability of findings, deviation is analyzed, too. For instance in manufacturing companies or in high frequent transport concepts (e.g., JIS) neither too early nor too late deliveries are acceptable. According to the expert interviews, the delivery windows for store delivery has typically a time span of +/-15 minutes before or after a defined time point. To improve generalisability of findings, again an alternate delivery window size of +/- 30 minutes is analyzed. Additionally, the inventory in the SC is evaluated according to the inventory levels at different sites as well as the amount of goods on transport vehicles. Furthermore, *emissions* can be calculated for both the order level and the system perspective. Emissions are calculated based on the database provided by Infrac (2011) on CO₂, NO_x and particle emissions for different

transport distances, routes and inclination profiles as well as transport vehicle types.¹⁰⁶ A calculation of transport costs is not possible for the simulation study. Therefore, encompassing data on transport cost rates for different transport distances, rates for capital commitment caused by different inventory levels, transshipment costs and overhead costs are necessary. In particular, for the operators and carriers these data are competition-relevant and thus, not available for the simulation study.

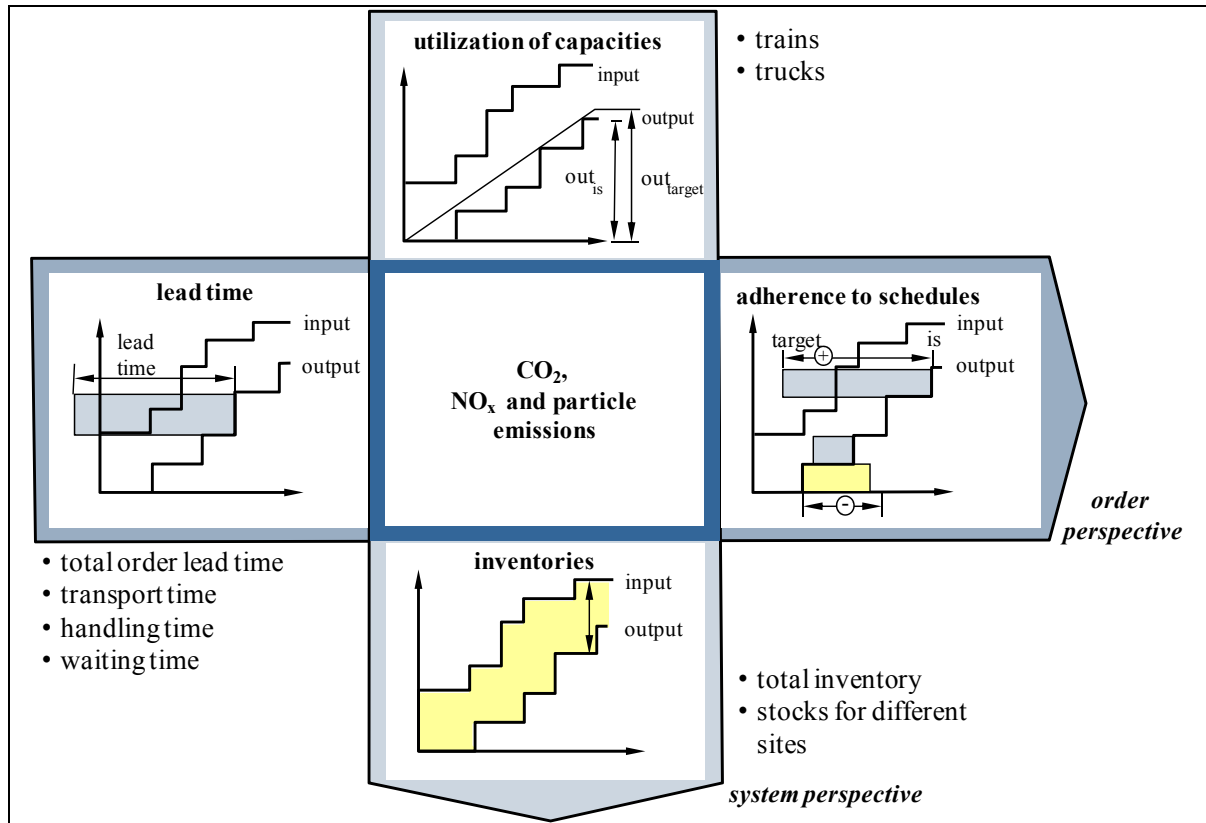


Figure 5 - 3: Performance indicators for the evaluation of simulation scenarios.¹⁰⁷

Initially, the performance effect of the CT integration in general is analysed. It is assumed that the integration of the regular line CT into the given lean SC concept leads to the general improvement in SCP. Following the argumentation line of the conceptual framework, the improvement can affect the different dimensions of SCP.

¹⁰⁶ cf. Infras (2011b).

¹⁰⁷ Illustration based on findings in section 2.3.4.

5.3.5 Development of Statements on Expected Simulation Results

Impact of CT Integration on SC Efficiency

Following the considerations in section 2.3 and 4.1, it must be assumed that additional processes generally cause longer lead times (*SCP in terms of lead times*).¹⁰⁸ Furthermore, it can be assumed that the integration of CT leads to more stable lead times and a higher adherence to schedules because in comparison with unimodal road transport on main haulage there are no delays (*SCP in terms of adherence to schedules*). Shorter lead times, reduced transport distances on the road and bundled transport volumes lead to a lower number of required trucks. Thus, the integration of CT may lead to a reduction in overall SC costs (*SCP in terms of costs*). Finally, the shorter transport distances on roads, the bundling effect on main haulage and the better emissions balance of rail transport in comparison with road transport lead to a decrease in emissions levels (*SCP in terms of emissions*).

These considerations are summarised in a first and a second statement on the expected results for the simulation study:

E₁: The integration of CT impacts SCP in terms of (a) enhancement of lead time, (b) adherence to schedules and (c) reduction of emissions (in comparison with a unimodal road transport concept).

E₂: The integration of CT allows the (a) reduction of road transport vehicles and the (b) improved utilisation of road transport vehicles.

Impact of CT Integration on SC Effectiveness

Furthermore, it is assumed that SC effectiveness is influenced by the integration of CT. Following the consideration in sections 2.3 and 4.1, it can be assumed that the total inventory in the SC increases because of the longer lead times. In comparison with unimodal road transport, time flexibility, e.g., expressed by short-term changes of transport quantity or transport time, decreases since the CT concept depends on defined train schedules with restricted capacity and a comparably high level of fixed costs. These considerations are summarised in a third statement on the expected results of the simulation study.

¹⁰⁸ The CT concept offered by *Swiss Post* is based on comparably short lead times for the rail transport. Owing to the preferred usage of 'pendel trains' the trains have an even higher speed than trucks have. For some specific configurations it can even be assumed that despite the additional handling and transshipment times CT is even faster than is unimodal road transport.

E₃: CT integration leads to an (a) increase in the total inventory level and (b) a reduction of time flexibility (in comparison with a unimodal road transport concept).

Although the last statement describes a decline in SCP in comparison with unimodal road transport, the integration of CT must not be refused. This statements can serve as the basis to discuss the trade-off relationships between the 'classical' SCP dimensions and the rather 'innovative' dimensions of adherence to schedules and emissions (cf. sections 2.1 and 2.3).

These three statements serve to explain the general influence of CT integration. The as-is simulation model (basic scenario) and CT scenario I serve as benchmarks for the analysis of the 'fit' between CT and SC concepts.

SCP Influence of the Alignment of the SC Concept to the CT Concept

To make statements on the impact on SCP of the goodness of the 'fit' between CT and SC concepts different adaptations to the SC concept are analysed (CT scenario II, III and IIIa). For each scenario only one parameter is varied while all others are kept constant.

Adaptations of the Production Concept

The adaptation of arrival and departure times in the SC leads to a reduction in waiting times. Thus, it can be assumed that the harmonisation of production arrival times with departure times in CT reduces total lead times as well as adherence to schedules. Furthermore, this synchronisation of processes increases time flexibility; because of the aligned arrival and departure schedules, the planning horizon is improved and enhanced for all SC members. Thus, the shifting of transport quantities or transport times can easily be accomplished. According to the considerations in section 3.3.3, production arrival times can be influenced by changes in the production control logic as well as changes in the production and the stocking type. The considerations are summarised in the fourth statement on the expected results:

E₄: The harmonisation of production arrival times with the CT concept leads to a (a) reduction in lead times, (b) increased time flexibility and (c) improved adherence to schedules.

Adaptations of the Distribution Concept

Comparable considerations are valid for the adaptation of the distribution concept (cf. section 3.3.4). As explained above, delivery windows are gaining increasing interest in

practice. In particular, for store deliveries in urban areas, the delivery windows are small and adherence to these schedules is critical. On one hand, regulations, especially in city centres, restrict the length of the delivery windows. On the other hand, there are specific personnel for the placement of goods in the store. Usually, there are no storage capacities, only buffers for the delivered goods. Thus, the goods must be placed on the shelves as soon as they arrive. The expert interviews showed that the store manager tends to be comparably inflexible in the adaptation of delivery time windows and the planning of personnel for unloading. However, the simulation is supposed to show the advantages of an enhancement and the harmonisation of delivery windows with the CT concept. The enhancement leads to an improvement in adherence to schedules.¹⁰⁹ This can positively influence time flexibility, too. The enhancement and harmonisation of delivery windows can also reduce overall lead times because waiting times can be avoided. These considerations are summarised in the fifth statement on the expected results:

E₅: The (a) enhancement and the (b) harmonisation of store delivery windows with regards to the CT concept leads to (1) a reduction of lead times and (2) an improvement in adherence to schedules.

As discussed for production concepts, the enhancement of delivery times and thus, total lead time improves the applicability of the CT concept. In retail, there are often short delivery times, for instance same day deliveries, with morning orders and deliveries in the afternoon. Usually, this planning horizon is not sufficient for the integration of CT concepts. Thus, in a sixth statement on expected results aims at the enhancement of delivery time between stores and DCs and manufacturers. It is expected that the enhancement of delivery times causes an increased lead time and thus, increases total inventory, but positively influences adherence to schedules and time flexibility because of the longer planning horizon and thus, the utilisation of transport vehicles.

E₆: The enhancement of delivery times leads to (a) increased lead times, (b) increased inventory levels, (c) improved adherence to schedules, (d) time flexibility and the (e) utilisation of transport vehicles.

The following section discusses the data gathering and editing process as the basis for the development of a simulation model.

¹⁰⁹ However, it may cause increased personnel costs.

5.4 Step 2: Data Gathering and Editing for Model Configuration and Validation

This section describes the process of data gathering and editing for the purpose of model configuration and validation. Different data sources were the bases for the simulation model.¹¹⁰ Expert interviews with different SC actors were conducted. Additionally, documents (e.g., time schedules, process descriptions and databases, as well as the results of Internet research) were combined to reach internal and external validity.

Expert Interviews

Manor provided encompassing information on the recent SC concept and ideas on the integration of CT into SC concepts. These expert interviews generated a general understanding of the SC concept, SC structure, partners and locations, as well as product- and market-specific characteristics. Furthermore, the specific production and distribution concepts (including the applied I&C systems) were specified, e.g., the applied planning and control mechanisms, logistics and transport concepts, specific target systems and transport quantities, as well as the infrastructural characteristics of different SC sites.

The expert interviews with *Swiss Post* focused on the process-oriented, organisational and technical aspects of the transshipment and handling of the CT terminal as well as for rail transport, e.g., transport and handling times, planning advances, flexibility regarding opening times, transport quantities, short-term changes and train schedules.

Document Analysis

Manor provided a number of different documents on delivery windows, ramp opening times, loading, unloading, order picking and handling times, transport times for the different DCs and stores, delivery schedules (time and day), number of deliveries per week and the allocation of specific transport routes, transport routes, transport modes, road carriers and capacity usage per transport route and day of the week, as well as order lead times. The experts stated that for the loading and unloading of one pallet, 1 minute is necessary. Additionally, an access database was provided including all orders

¹¹⁰ cf. Bortz et al. (2006), pp. 296.

by load carrier from January 2010 to October 2010. It includes information on demanded quantities, type of load carrier, type of goods (priority and non-priority), corresponding transport and dates for all the stores from the two DCs in Möhlin and Hochdorf.

Swiss Post provided the train schedule for package transport between the three terminals in Härkingen, Frauenfeld and Daillens. This schedule includes the transport times, handling times and earliest and latest delivery times according to regulation policy and terminal opening times. Furthermore, a documentation of all technical transport vehicles, locomotives, wagons, cranes, containers and load carriers used for CT was made available. The terminals are specified in terms of track length, track capacity and crane scope. According to the experts, the loading and unloading processes at the terminals take 30 minutes.

Table 5 - 2 provides an overview on the sites included in the simulation model.

No.	Site	No.	Site	No.	Site
1	DC Hochdorf (DC HOV)	7	Monthey (MON)	12	Vésenaz (VES)
2	DC Möhlin (DC MOE)	8	Morges (MOR)	13	Vevey (VEV)
3	PF Sion (PF SIO)	9	Nyon (NYO)	14	Yverdon (YVE)
4	Chavanne (CHA)	10	Sierre (SIE)	15	Terminal Härkingen (T HAE)
5	Geneva (GEN)	11	Sion (SIO)	16	Terminal Daillens (T DAI)
6	Lausanne (LAU)				

Table 5 - 2: Sites modelled in the simulation.

Literature Review on Transport Emissions

For the evaluation of transport emissions, four key figures were analysed: fuel consumption as well as CO₂, NO_x and particle emissions.¹¹¹ There are significant differences regarding these emission factors for the transport modes. Figure 5 - 4 illustrates these differences in reference to emissions per ton kilometers (tons multiplied by kilometres). The illustration shows that rail and inland vessels gain advantage over the truck, but especially over air cargo transport.¹¹² Nevertheless, the thesis in hand focuses on road and rail transport.

¹¹¹ cf. Infrac (2011a).

¹¹² cf. Umweltbundesamt (2009), p.14.

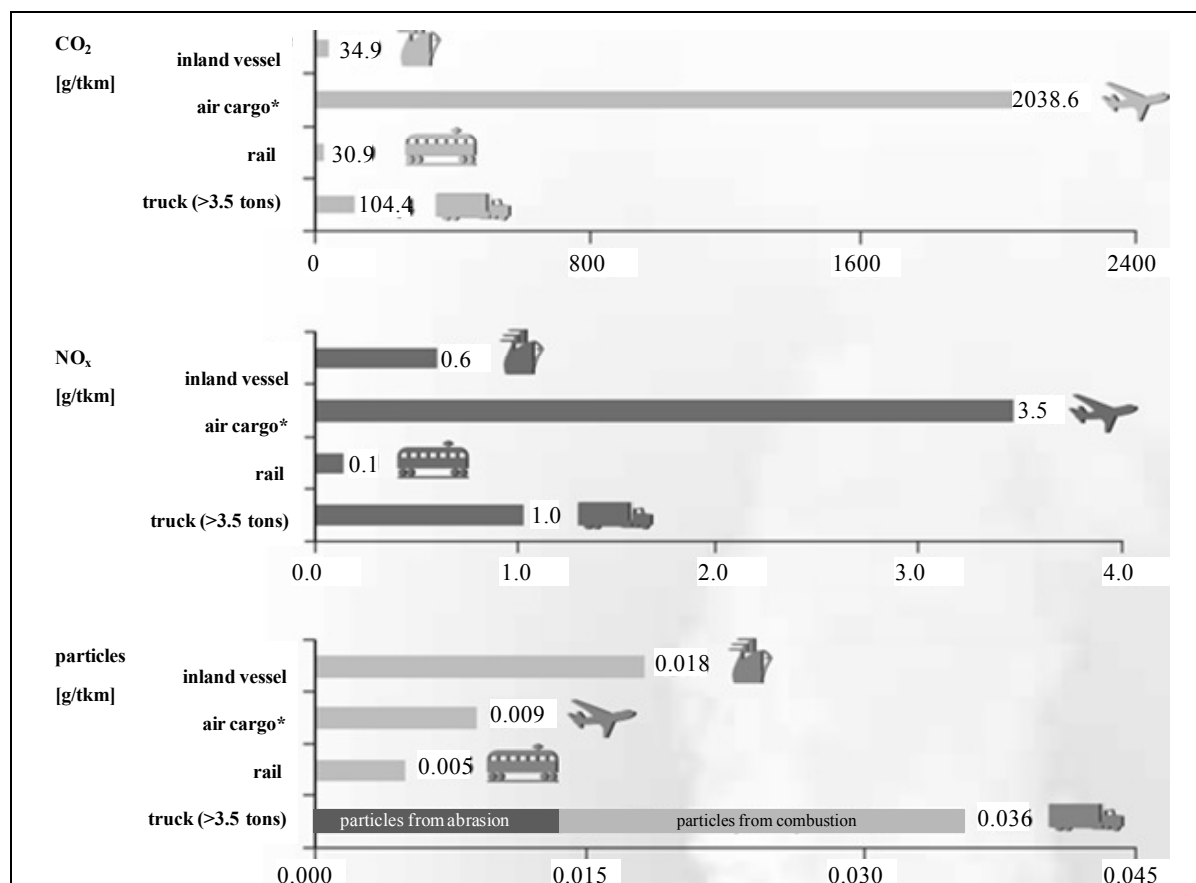


Figure 5 - 4: Comparison of CO₂, NO_x and particle emissions for different transport modes (under consideration of all climate-related effects of air cargo).¹¹³

Although political debates primarily focus on CO₂ emissions, these are not significant in the differentiation of transport vehicles according to the exhaust emission standards. Emission factors are provided by Infrac (2011) in the Handbook of Emission Factors for Road Transport (HBEFA).¹¹⁴ This database contains data on the emissions for different road types, inclinations, traffic situations, vehicle types, utilisation levels and emission categories. For the simulation study, standard emission factors for the traffic compilation of emission categories on the basis of 2010 and for an average utilisation of transport vehicles were used. Since the simulation model does not include transport quantities with weight information, average values were applied on a vehicle basis.¹¹⁵

Reh (2010) provides data on average emissions for trains.¹¹⁶ However, it must be kept in mind that the emission factors depend on the type of locomotive as well as the train

¹¹³ cf. Ibid., p.14.

¹¹⁴ cf. Infrac (2011a).

¹¹⁵ cf. Infrac (2011).

¹¹⁶ cf. Reh (2005), p. 136.

weight. Following Reh (2010), it is assumed that there is a share of diesel and electric locomotives on the train routes. Furthermore, for the fuel consumption of rail transport processes, LUBW (2011) presents values referring to the *DB AG* and *Aviso*¹¹⁷ in terms of different fuel consumption factors depending on the locomotive type for service type (line vs. shunt services).¹¹⁸ According to LUBW (2011), freight transports on line connections have an average fuel consumption of 3.3 L/train-km. For the simulation study, it was assumed that an average of 30 shipments is transported by one train.

average emission for train transport	per train-km
NO _x	131.619 g
particle	3.462 g
CO ₂	7117.5 g
fuel consumption	3.3 L

Table 5 - 3: Emission factors for rail transport.¹¹⁹

Further emissions, for instance those caused by shunting services and terminal processes, were excluded from consideration.

Table 5 - 1 provides an overview of the different data gathered for the simulation study and the specific data sources.

category	simulation object / variable	data sources
SC network	<ul style="list-style-type: none"> production sites DCs transshipment points stores 	<i>Manor</i> <i>Swiss Post</i>
transport routes	<ul style="list-style-type: none"> route segments transport times route profiles inclination profiles transport schedules (rail and road) 	<i>Manor</i> <i>Swiss Post</i>
products	<ul style="list-style-type: none"> production schedule / quantities product types (priority/non-priority) delivery times volume per product type 	<i>Manor</i>
performance requirements for delivery	<ul style="list-style-type: none"> demand per day / store delivery windows vendor dock opening times 	<i>Manor</i>
transport vehicles / terminals	<ul style="list-style-type: none"> transport capacity terminal and overhead capacities loading / unloading / processing time 	<i>Swiss Post</i> Internet and literature review
external restrictions	<ul style="list-style-type: none"> weekend driving bans night driving bans inner-city driving bans emissions profiles (road and rail) 	<i>Swiss Post</i> Internet and literature review

Table 5 - 1: Overview of data sources and data provided.¹²⁰

¹¹⁷ Land register of Baden-Wuerttemberg, Germany.

¹¹⁸ cf. LUBW (2002), p. 17.

¹¹⁹ cf. Reh (2005), p. 136.

¹²⁰ For a list of conducted interviews, see Appendix A-II.

In an iterative process, the data gathered was enhanced and specified using additional telephone interviews and email contact.

Data Editing

To use the provided data, a comprehensive editing process was necessary. This editing process made the information suitable for processing in the simulation tool and the underlying database. Namely, data was edited and summarised in table form and saved as text files.¹²¹ In total, 21 files were created as databases for the simulation study. These text files were the bases for the Oracle database, which was linked with the simulation tool (cf. Appendix D).

Transport Routes, Distances and Speed

The *transport routes* were enhanced by additional information on the different route segments, the required transport time and the allocated transport vehicle. The distances between the different SC sites and the street profiles (share of highway and non-highway distances) were added based on an online route planning instrument.¹²² In response to the expert interviews confirmed by literature, an average transport speed of 50 km/h was determined for all street profiles.¹²³ An average transport time was added based on this information for each transport route. Following a study by the University of Vienna, an inclination profile for all transport was applied.¹²⁴ Table 5 - 4 shows the assumed inclination profile for the calculation of transport emissions.

	inclination +6%	inclination +4%	inclination +2%	inclination +0%	inclination -2%	inclination -4%	inclination -6%
share of entire transport distance	5%	10%	20%	30%	20%	10%	5%

Table 5 - 4: Standardised inclination profile.¹²⁵

¹²¹ These text files were used for the storage and exchange of simply structured data. 'csv' stands for 'comma-separated values'.
¹²² www.maps.google.com. Documented in Appendix D.

¹²³ cf. LUBW (2011); ASTRA (2010); Bühler (2005), pp. 145. Speeds were confirmed by expert interviews. For further information on average transport speeds for different carriers, see Kille et al. (2008); Bühler (2005), pp. 145.

¹²⁴ cf. Sihn et al. (2010).

¹²⁵ cf. Ibid.

Table 5 - 5 shows an extract from the table of defined route segments.

route segment	distance [km]	start	destination	highway [%]	non-highway [%]	transport time [sec.]
...						
route segment 30	207	DC HOV	CHA	94.69	5.31	10 800
route segment 31	260	DC HOV	GEN	94.23	5.77	13 620
route segment 32	209	DC HOV	LAU	93.78	6.22	10 980
route segment 33	213	DC HOV	MON	94.37	5.63	11 160
route segment 34	209	DC HOV	MOR	94.74	5.26	10 920
route segment 35	235	DC HOV	NYO	94.89	5.11	12 240
route segment 36	272	DC HOV	SIE	95.22	4.78	14 100
route segment 37	257	DC HOV	SIO	95.33	4.67	13 320
route segment 38	190	DC HOV	VES	90.53	9.47	10 200
route segment 39	188	DC HOV	VEV	93.09	6.91	9 900
route segment 40	176	DC HOV	YVE	93.18	6.82	9 300
... extract. Full list documented in Appendix D.						

Table 5 - 5: Extract of route segments defined for the simulation with distance, street profile and transport time.¹²⁶

The different transport routes were compiled using the different route segments. Furthermore, a primary and specific transport vehicle and start time were defined for each route.¹²⁷ Table 5 - 6 lists the primary transport routes. In the simulation model, additional transport routes with additional transport resources were defined for cases where the demand exceeds the capacity of the primary transport vehicle.¹²⁸

¹²⁶ Full list Appendix D.

¹²⁷ In an additional table, t_vehicle, the transport capacity in pallet equivalents is included.

¹²⁸ There is an additional table (t_starttime) that defines on which days the transport is accomplished.

route	route segment	start	destination	transport resource	transport time [sec.]	start time
H 60	30	DC HOV	CHA	V I	10 800	11:30 AM
	125	CHA	MOR		900	
	175	MOR	NYO		1 500	
H 70	31	DC HOV	GEN	VII	13,200	11:00 AM
	141	GE	VES		1,200	
H 63	32	DC HOV	LAU	V III	10 980	11:00 AM
	154	LAU	VEV		1 500	
H 75	33	DC HOV	MON	V IV	11 160	12:30 AM
H 220	28	DC HOV	PF SIO	T I	13 320	4:30 PM
	111	PF SIO	SIO		1 020	
	201	SIO	SIE		1 080	
H 240	342	DC HOV	PAY	V V	8 220	4:00 PM
	339	PAY	YVE		2 700	
M 3	52	DC MOE	CHA	V VI	12 480	11:00 AM
	125	CHA	MOR		2 700	
	175	MOR	NYO		1 500	
M 1	53	DC MOE	GEN	V VII	12 780	10:00 AM
	141	GEN	VES		1 200	
M 2	54	DC MOE	LAU	V VIII	10 140	10:45 AM
	148	LAU	MON		2 700	
	167	MON	VEV		4 500	
M 24	343	DC MOE	PAY	V IX	7 320	2:15 PM
	339	PAY	YVE		3 600	
MS 1	46	DC MOE	DC HOV	T II	4 920	2:30 PM

Table 5 - 6: Primary transport routes, transport resources and start times.¹²⁹

Demand and Transport Quantities

Manor provided data about the *daily demand* per store and per DC for all considered stores and the two DCs in between. From this demand, transport quantities were calculated. The database contained the demand per store and for the specific product types, as well as the specific load carriers for each day from January 2010 to September 2010. The information on the different load carriers allowed the calculation of so-called pallet equivalents. This means that according to a specific calculation key provided by *Manor*, demand quantities were standardised. For the analysis of the CT integration, only the differentiation into priority and non-priority goods was modelled.¹³⁰ Thus, based on this standardisation of demand quantities to pallet equivalents, the average demand per store, per DC and per priority class were calculated.

To model the fluctuations in demand and transport quantity, a comprehensive analysis of this demand data was necessary. As a first step, a visual analysis was conducted. As

¹²⁹ The values for the additional routes are identical, but different transport vehicles are used.

¹³⁰ Priority goods must be delivered to the store in the next delivery window. Non-priority goods can have longer lead times and can be delivered to the store whenever there is transport capacity available.

a second step, a univariate analysis of variance was used to analyse the impacts of different parameters on the demand per store, per DC and per priority class.

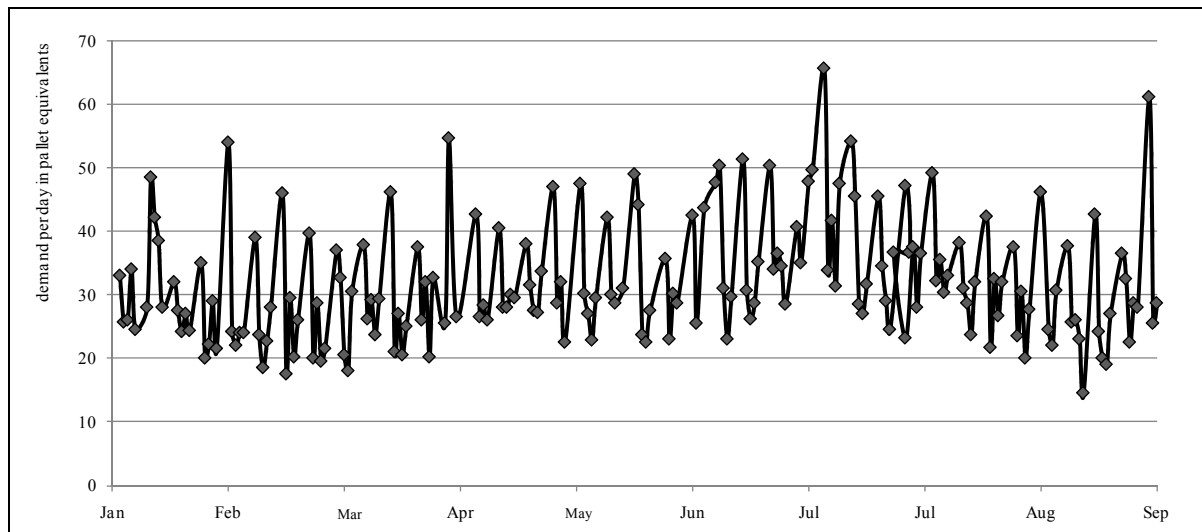


Figure 5 - 5: Example demand history for delivery to the store in Geneva from DC Hochdorf for prioritised goods from January – September 2010 in pallet equivalents.

Table 5 - 6 shows the demanded pallets of one type of goods, one store and one DC. The illustration shows that there were no obvious regular fluctuations over the analysed period.

As a result of the high fluctuations in demand, it was not possible to identify one specific demand value for the simulation. Therefore, a univariate analysis of variance was conducted to analyse the influences that affect the variability of demand. Figure 5-8 indicates that time-specific aspects strongly influence these fluctuations. Three different influence factors were analysed by ANOVA.¹³¹ The three different predictor variables *month*, *month phase* (1st - 4th quarter of the month) and *weekday* were investigated in three separate settings.¹³² In each analysis, the effect on the dependent variable *demand quantity* was also provided (partial η^2). By means of the example results for the store in Yverdon, the findings of the ANOVA are introduced. The ANOVA showed that monthly effects were not found to be significant and thus did not need to be considered in the simulation model ($F=0.396$; partial $\eta^2 = 0.023$). Also, the impact of the *month phase* was found to not be significant ($F=0.376$; partial $\eta^2 = 0.08$). For weekdays, the analysis showed a significant impact ($F=138.189$; partial $\eta^2 = 0.749$). In

¹³¹ ANOVA = with SPSS 18.

¹³² The H_0 -hypothesis states that there is no relationship. SPSS shows the probability p for the H_0 -hypothesis, as well as the proof of statistic F.

conclusion, the only predictor that showed a significant effect on *demand quantity* was the *weekday* variable. Thus, the weekday served as a basis for the calculation of different demand quantities for the simulation model.

Figure 5 - 6 supports this finding. The illustration shows that in each month, the number of demanded pallet equivalents obviously differs for the different weekdays. On Thursdays, the store in Yverdon receives no orders.

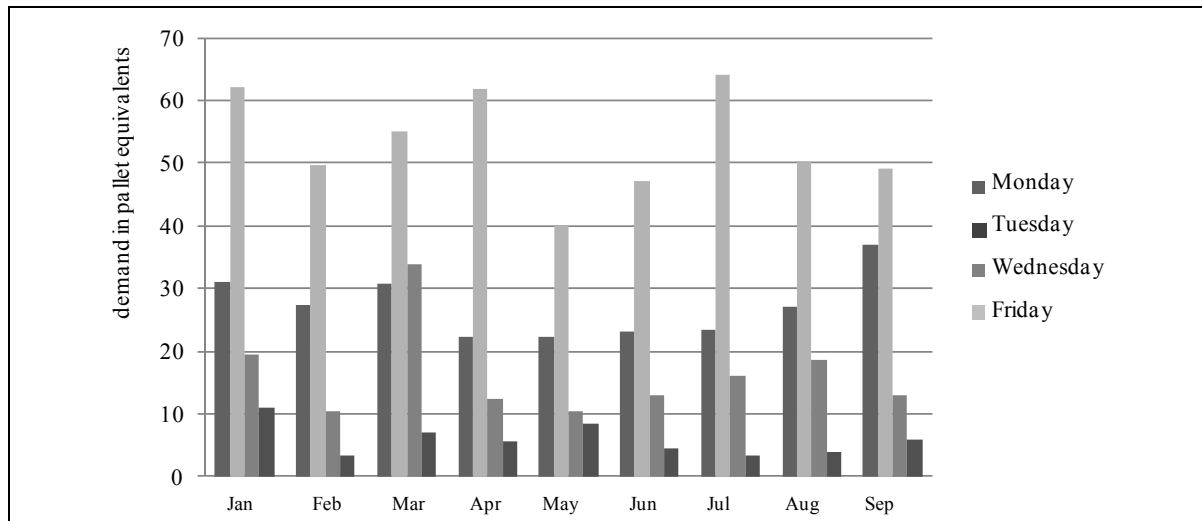


Figure 5 - 6: Demand in pallet equivalents per weekday for prioritised goods for the store in Yverdon from DC Möhlin.

Table 5 - 7 shows the average demand and the standard deviation per weekday for the transport of prioritised goods from DC Hochdorf and DC Möhlin to the stores. This data was the basis for product generation in the simulation model. According to a specific schedule, the defined amount of pallet equivalents is generated for transport to the destination store.

start	destination	Monday	Tuesday	Wednesday	Thursday	Friday	generation time
DC HOV	CHA	15	18	10	12	15	11:00 AM
DC HOV	GEN	40	31	27	24	28	10:00 AM
DC HOV	LAU	18	16	15	13	13	10:20 AM
DC HOV	MON	17	0	20	11	10	12:00 AM
DC HOV	MOR	6	9	0	9	7	11:00 AM
DC HOV	NYO	7	1	0	14	2	11:00 AM
DC HOV	SIE	20	12	0	4	31	9:00 AM
DC HOV	SIO	15	10	0	3	31	9:00 AM
DC HOV	VEV	19	14	15	13	13	10:20 AM
DC HOV	VES	8	5	8	0	8	8:00 AM
DC HOV	YVE	11	6	1	0	20	3:10 PM
DC MOE	CHA	8	10	9	9	9	9:15 AM
DC MOE	GEN	20	19	24	18	19	7:45 AM
DC MOE	LAU	9	12	12	10	11	8:15 AM
DC MOE	MON	9	0	14	8	8	8:10 AM
DC MOE	MOR	5	6	0	9	5	9:15 AM
DC MOE	NYO	4	1	0	6	2	7:05 AM
DC MOE	SIE	2	1	0	4	2	7:20 AM
DC MOE	SIO	2	2	0	5	3	7:25 AM
DC MOE	VEV	9	9	11	8	8	8:20 AM
DC MOE	VES	3	4	5	0	8	4:30 PM
DC MOE	YVE	6	4	1	0	12	11:45 AM

Table 5 - 7: Average demand for prioritised goods per weekday and store.¹³³

After this rather general explanation on the data gathering and editing process, the following section introduces the development, validation and verification of the simulation model.

5.5 Step 3: Development, Validation and Verification of the Simulation Model

This section addresses the development, validation and verification of the simulation model. Therefore, the SC concept and the CT concept were analysed, simplified, modelled, formalised and, finally, implemented. Several verification and validation steps ensured the compliance of the developed model with the as-is situation (external validity), the functioning of the model (internal validity) and suitability for the defined research target. A sensitivity analysis ensured that the model was valid for a defined range of different input and output parameters, in particular for different demand situations.¹³⁴

¹³³ The demand for non-prioritised goods can be found in Appendix B.

¹³⁴ The members of the V-Research group in Vorarlberg were the partners supporting the development of the formalised and the executable model.

5.5.1 Conceptual Model

A conceptual model serves to abstract the real or the scenario system. This step can be equated with a simplification of reality.¹³⁵ The formalisation of the conceptual model means the development of the implementation in the executable simulation model.¹³⁶ Different instruments are therefore available for this purpose, such as pseudo-code, structograms, entity-relationship diagrams or UML notation.¹³⁷

Conceptual model building means transferring the problem formulation and model requirements to a determination of what is modelled in what way.¹³⁸ Thereby, the conceptual model is independent of the simulation tool used.¹³⁹ The target and level of accuracy must be defined in this phase of the modelling process.¹⁴⁰ Assumptions are necessary if there are uncertainties about the real world behaviour. Simplifications are necessary to accelerate the simulation process in order to reduce data needs and to improve the transparency of the simulation model.¹⁴¹ In brief, the conceptual model describes the targets, input¹⁴² and output data,¹⁴³ scope, level of detail, assumptions and simplifications relevant to the simulation model.¹⁴⁴

System Limits and Level of Detail of Simulation Study

Figure 5 - 7 illustrates the simplified model of the central simulation objects. The simulation model includes two DCs, two terminals, one regional cross-docking platform and eleven stores in Western Switzerland. The flow of goods between the sites is modelled by the different transport vehicles that travel via defined transport routes. Temporal and spatial information on all events (e.g., generation of goods, loading, unloading, transshipment, transport and waiting) was generated for each object.

¹³⁵ cf. Zeigler (1984).

¹³⁶ cf. Rabe et al. (2008), p.49. The step of formalisation is often skipped due to a project's financial restrictions. cf. Ibid., p.128.

¹³⁷ cf. Ibid., p.48.

¹³⁸ cf. Pidd (2003).

¹³⁹ cf. Fishwick (1995).

¹⁴⁰ cf. Robinson (2008).

¹⁴¹ cf. Ibid., p.279.

¹⁴² The *inputs* (or experimental factors) are those elements of the model that can be altered to effect an improvement in, or provide a better understanding of, the problem situation. They are determined by the objectives. cf. Robinson (2004), p.66.

¹⁴³ The *outputs* (or responses) report the results from a run of the simulation model. These have two purposes: first, to determine whether the modelling objectives have been achieved; second, to point to reasons why the objectives are not being achieved, if they are not. cf. Ibid., p.66.

¹⁴⁴ cf. Ibid., pp. 63.

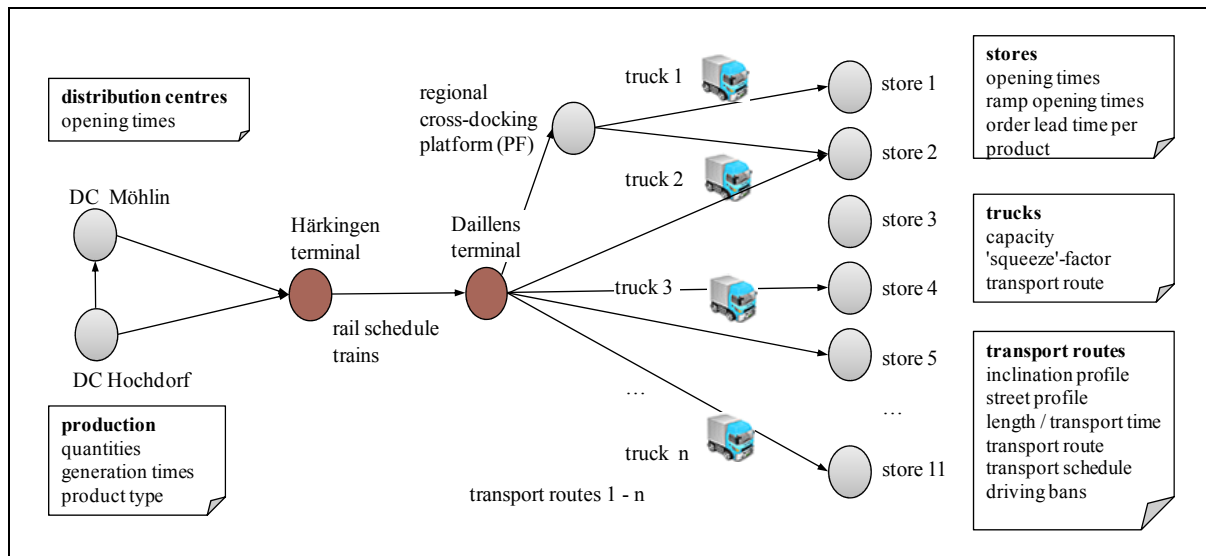


Figure 5 - 7: Conceptual model simulation scenario with CT.

Level of Detail

To analyse the influence of CT integration in the SCP, it was not necessary to model partial processes at the different sites.¹⁴⁵ This means that each site was modelled with only one process. For instance, only one process with a certain duration was specified to model all processes in the CT terminals (e.g., entry, administration, waiting and transshipment) because the lengths of the different partial processes were not relevant for the given research target. This reduction of detail reduces the complexity of the model, but does not restrict the resilience of the simulation results.

Input Parameters

This section gives an overview of the central input data. Figure 5 – 8 shows the different input parameters, the dependencies and connections in a simplified UML class diagram.¹⁴⁶ For object-oriented modelling, a class defines a common structure and a common behaviour of objects (classification). It is visualised by a rectangle with a name (bold) and, optionally, attributes, operations and characteristics separated by horizontal lines.

¹⁴⁵ cf. Rabe et al. (2008), p.69.

¹⁴⁶ A class diagram serves to the visualisation between different classes, interfaces and relations.

As described above, the data was stored in text files.¹⁴⁷ The adaptation of this input data was the central factor to setting up the different simulation scenarios. All tables can be found in Appendix D, ordered by the different scenarios.

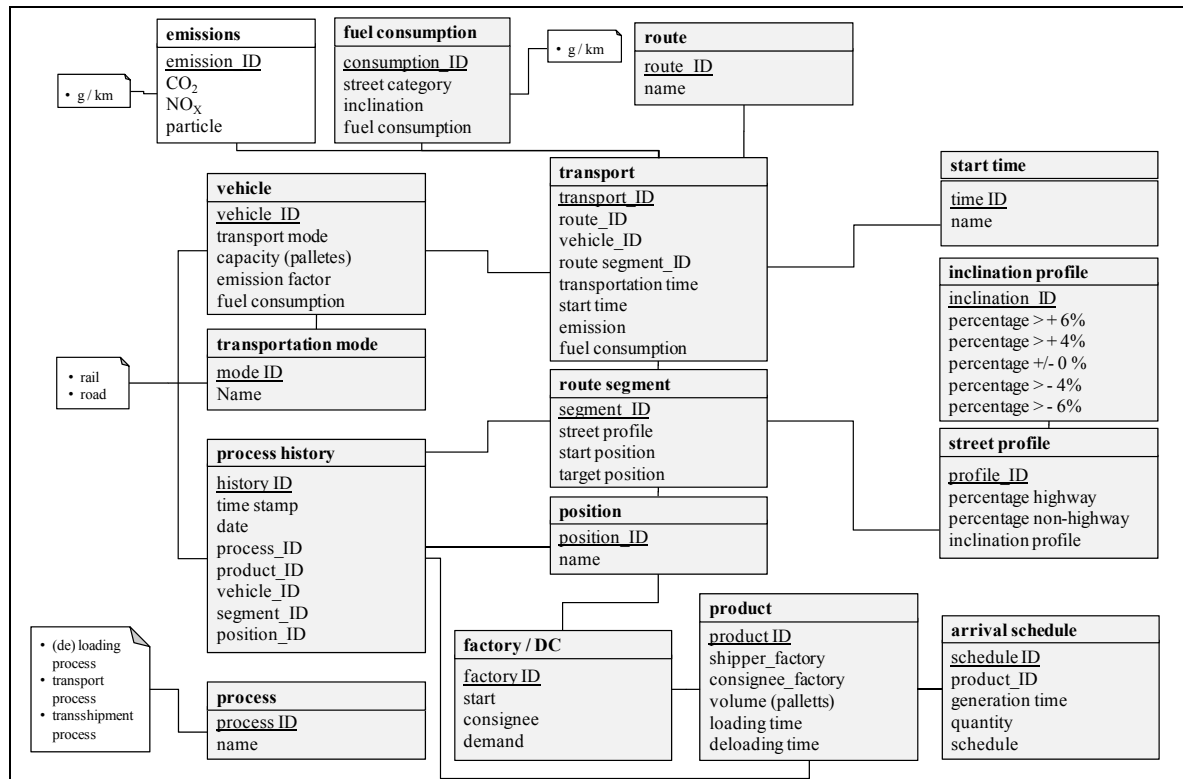


Figure 5 - 8: Data model for the simulation study (simplified UML notation).

The input parameters for the simulation study were:

- A list with the different sites in the SC, such as the stores, the CT terminals and the DCs (position_ID).
- A list with the operating times of all the stores (factory_ID).
- A list with the generation time and quantity of goods in the DCs per store, priority class and the weekday (schedule_ID).
- A list with the transport schedules (transport_ID; time_ID) for different transport routes (route_ID) with defined route segments (segment_ID). Furthermore, the specific transport vehicle (vehicle_ID) and the transport mode (mode_ID) were determined.
- A list with the route segments (segment_ID). Each route segment was specified by an inclination profile (inclination_ID) and a street profile (profile_ID). The street

¹⁴⁷ The different files are included in Appendix D.

profile determined the share of highway and non-highway transport distance.

- A list with the handling, transshipment and additional processes and the required times (processes_ID).
- A list with the emission and fuel consumption factors per vehicle and transport distance (emission_ID; consumption_ID).

Basic Assumptions

Some general assumptions and simplifications were necessary for the modelling of the SC concept. In particular, assumptions regarding the (1) demand and transport quantities and the (2) duration and fluctuation of handling and transport processes were necessary. The calculation of emissions included the factor of (3) inclination profiles. Since the simulation model does not include production facilities, it is assumed that adaptations of the production concept could be modelled by adapting the (4) generation of goods in the DCs.

(1) Fluctuations in Demand

Demand and transport quantities in retail underlie different temporal fluctuations. The univariate analysis of variance showed that up to 75% of the fluctuations in demand can be explained by the impact of weekdays.

However, the analysis of the average demands and the standard deviations, as well as the discussions with the interview partners, encouraged the analysis of different demand situations. Thus, the simulation study considered four different demand situations.

(1) Normal demand situation. The mean demand value per weekday was applied (cf. Table 5 - 7 and Appendix B).

(2) Reduced demand situation. Since standard deviation was not consistent for all stores, based on the expert interviews a reduced demand situation was analysed using a reduction in the mean demand of 20% (cf. Appendix D).

(3) Increased demand situation I. A 20% increase in demand equals the average value of standard deviation over the different stores. The expert interviews confirmed that a 20% increase in demand is commonly experienced and thus this increase was chosen for the sensitivity analysis (cf. Appendix D)

(4) Increased demand situation II. A 50% increase in demand equals the peak values of demand for the different stores. The expert interviews confirmed that a 50% fluctuation in demand is experienced less commonly but still regularly. Thus, the interviews encouraged the choice of a demand increase of 50% for the sensitivity analysis (cf. Appendix D).

Extraordinary demand situations were not considered. Usually, in freight transport the

capacity dimensioning is not always oriented to maximum demand situations.¹⁴⁸ In accordance with the views of the interview partners, the analysis focused on the normal demand situation. Furthermore, the train capacities were used to the maximum for the 50% increased demand situation. A further increase would negatively affect the generalisability of the results.

(2) Duration and Fluctuation of Handling and Transport Processes

Based on the expert interviews, it was assumed that *transport, loading and transshipment times* have mean values depending on the transport distance, transport mode and shipment size. For the loading, the unloading rate was assumed to be an average of 1 minute per pallet equivalent; for the transshipment processes, an average time of 30 minutes per truck shipment was assumed. The transport times for road transport were calculated based on the transport distance and an average speed of 50 km/h.¹⁴⁹ For rail transport, the transport time results were derived from the rail schedules provided. Delays and disruptions caused by congestion or different average velocities for different times or weekdays were – to a certain extent – integrated in the comparably low average speed of the trucks, as modeling explicit disruptions in road or rail transport was not possible.

(3) Emissions

The standardised inclination profile provided by Infras (2011) was used for the calculation of fuel consumption and emissions. Furthermore, the transport distance and the share of highway and non-highway distance were the bases for calculation. Values for the average loading and for the average share of emissions categories for trucks on the basis of data from 2010 were used. There was no available information on further influencing parameters, such as driving styles and the specific emissions categories of the transport vehicles, as well as the effects of different average speeds for different times and weekdays.

(4) Generation of Goods

Since no *production facilities* were included in the simulation model, the goods were generated in the DCs. This generation process can be understood as the goods' production. Thus, adaptations to the temporal generation of goods, e.g., arrival times, frequencies and quantities, were used to simulate changes to the production concept (cf. section 3.3.3).

¹⁴⁸ In retail, these situations can occur, for example, ahead and after a holiday period or because of specific marketing activities. The demands and the transport quantities can increase many times over for certain or peak time periods of a few days.

¹⁴⁹ On the basis of the expert interviews confirmed by literature. cf. LUBW (2011); ASTRA (2010); Bühler (2005), pp. 145. For rail transport, fixed transport times based on the transport schedule provided by the *Swiss Post* were used.

(5) Non-Priority Goods

To keep the complexity of the simulation model low, the sequence of order processing was defined by the two different product types: prioritised and non-prioritised products. There was no allocation of due dates to the specific orders. The configuration of the model made sure that priority goods were always transported to the store on the same day as they were generated. If the quantity of prioritised goods exceeded the capacity of the primary transport vehicle, a second vehicle was initialised. These additional transport vehicles were not implemented for non-prioritised goods. These goods stayed at the DC until the next primary transport had free capacity. In practice, the non-priority goods have a due date, too. Usually, the date is some time in advance (usually at least one week). The sensitivity analysis showed that for the simulation, all non-priority goods were taken to the destination in a timely manner.

5.5.2 Simulation Model

Based on the conceptual model, the executable simulation model was developed. The simulation tool Flexsim is used for implementation (cf. section 5.1.6). Activity diagrams were used to provide structured descriptions of the sequence of model configuration for each simulation run.¹⁵⁰ Appendix C-I illustrates the process for the configuration of a simulation model. It determines how and in which order the different simulation modules are generated. Appendix C-II visualises the formal structure of each simulation run, starting from the product creation to the final delivery.

The model generation in this thesis was based on the modular structure of Flexsim. Predefined routes can be added to the model by connection with an underlying database. The different sites (CT terminals, DCs and stores) and transport resources were generated and parameterised.¹⁵¹ At a defined time point, products were generated at the DC, loaded into a defined transport vehicle and taken on a defined transport route to their final destination. Flexsim stored the generated data as a text file.

Figure 5 - 9 shows a screenshot from Flexsim from an example SC.

¹⁵⁰ An activity diagram in UML notation allows an object-oriented description of programs and systems.
¹⁵¹ On the basis of an OBDC connection.

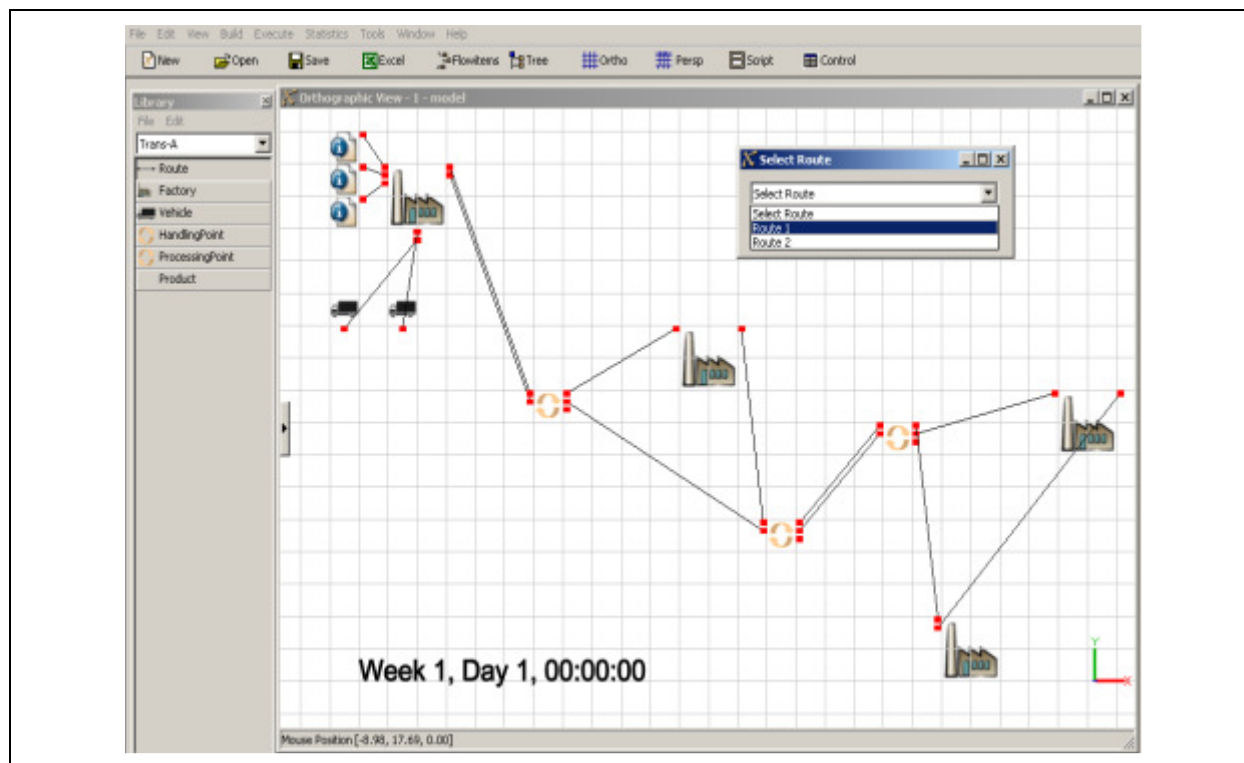


Figure 5 - 9: Screenshot from the simulation model in Flexsim.

Output Data as the Basis for the Calculation of Performance Indicators

The results of each simulation were stored in a text file. Data on all accomplished processes and events per object was saved (cf. `history_ID` in the UML-diagram in Figure 5 - 8; documented in Appendix D).¹⁵²

The '*lead time*' per order (pallet) resulted from the difference between the arrival and start time. The start time equals the product generation time. The arrival time equals the time point at the completion of unloading at the destination store.

The different '*lead time elements*', namely handling time, transport time and waiting time, were calculated per order. The *handling time* was the sum of all loading and unloading times of a certain type of goods. It was calculated by summing up the time span between the beginning and the end of the loading and unloading respectively transshipment process of the specific truck and/or train. The *transport time* resulted from the difference between the beginning and the end of all transport processes experienced by a certain pallet equivalent. The *waiting time* resulted from the difference between the order lead time and the transport and handling time.

¹⁵² Oracle Express 12.

The ‘*inventory level*’ was calculated as the integral of product generation at a certain time point and the product being removed from the system after the unloading at the store.¹⁵³ The inventory level in the transport process depended on two main factors: the demand quantity and the order lead time. The average inventory was calculated as the integral of the inventory over time per store. Figure 5 - 10 shows an example inventory course for delivery to the Chavannes store for products coming from DC Hochdorf for the as-is situation with normal demand. The curve shape shows two points for each product generation: one point for the prioritised goods and one point for the non-prioritised goods. The steep vertical decline of the curve with several data points visualises the storage of products and the discrete removal of pallet equivalents from the system. The area below this inventory course equals the integral of the curve and thus the average inventory (marked as a grey area). The curve shape is representative of all the stores and DCs.¹⁵⁴ For the given example, the results show an average inventory of 4.4 pallet equivalents for the transport, starting from the provision at the DC and terminating with the unloading in the store.

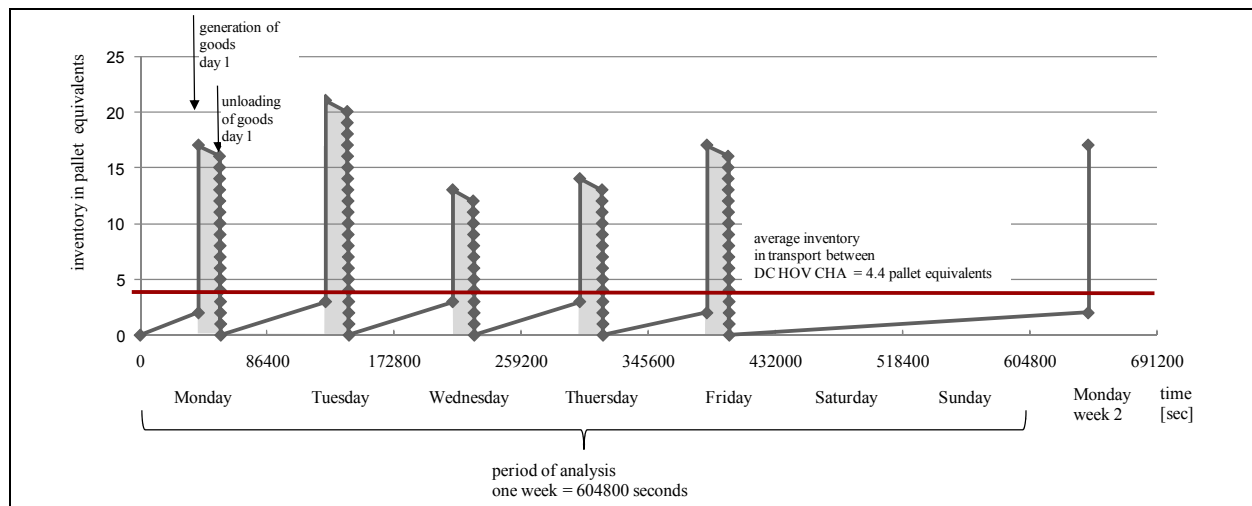


Figure 5 - 10: Example inventory course for delivery to the Chavannes store with goods from DC Hochdorf (grey = integral of inventory).

The ‘*adherence to schedules*’ was evaluated by the comparison of the actual arrival time at the store and the designated delivery window. The adherence to schedules can be calculated on the basis of four different key figures: (1) the deviation for a +/-15 minute time window, (2) the deviation for a +/-30 minute time window, (3) the delay for a +/-15 min-

¹⁵³ The inventory level is the basis for the evaluation of capital commitment costs.
¹⁵⁴ See Appendix D.

ute time window and (4) the delay for a +/-30 minute time window. The deviation number includes all the deliveries that were either too early or too late to meet the defined delivery window. The number of delays only includes the deliveries that are late. The ratio of deliveries on time and deviating or delayed transport vehicles equals the adherence to schedules as a percentage. Additionally, the average deviation and average delay from the target arrival time was calculated in minutes.

The '*utilisation of the vehicles*' can be calculated by the division of the maximum capacity and the actual capacity of each transport process.¹⁵⁵ Capacity utilisation in the first route segment was used for evaluation. The effect of declining capacity utilisation because of the unloading of partial deliveries (cf. section 3.3.1) was not considered.

The '*emissions*' can be calculated on the basis of the output data for CO₂, NO_x and particle emissions in grams for each route segment. This data can be converted to emissions per vehicle, weekday and transport route.

There was no specific data created by the simulation to measure or to evaluate '*flexibility*' and '*product quality*'. Thus, the impact of CT integration on flexibility and product quality in the SC concept is discussed based on the qualitative evaluation of the other simulation results.

The following section introduces the validation and verification steps that were performed to ensure the internal and external validity of the simulation model.

5.5.3 Validation and Verification

To ensure internal and external validity, the conceptual and the formalised models must pass the test of consistency and functionality. The executable model must compare with the behaviour of the real world system. Furthermore, verification between the implementation of the conceptual model in the form of the executable model must be verified. At last, the executable model must be validated in terms of the real world problem. Figure 5 - 11 illustrates the relationships between the real world problem, the conceptual model and the executable simulation model.

¹⁵⁵ A transport process here means the accomplishment of a total transport route.

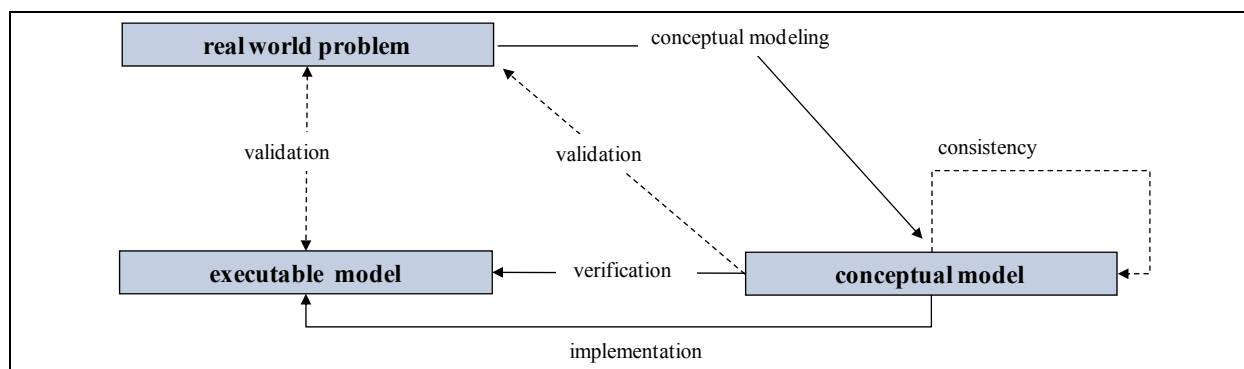


Figure 5 - 11: Conceptual model validation and verification.¹⁵⁶

Rabe et al. (2008) recommend that different validation and verification techniques are used for the different phases of a simulation study.¹⁵⁷ For the conceptual model, they recommend validation by means of a ‘review’¹⁵⁸ of the model with the experts from *Manor* and *Swiss Post*. Furthermore, validation and verification were ensured by so-called ‘face validity’: a dialogue with experts in the field of SCM and CT. These discussions served to quickly identify the mistakes and irregularities. Additionally, a ‘desk-checking’ process was accomplished.¹⁵⁹ This included the self-inspection of integrity, consistency and definiteness.

The verification of the model was based on several simulation runs to uncover any mistakes and abnormalities in the model. Initially, the impact of single changes in different input data was examined to ensure the correct functioning of the model. For instance, an increased demand in one certain store was modelled and the correct influence on the generated output data, e.g., the utilisation of the specific transport vehicle, was checked.

For validation purposes in particular, the comparison with the real system regarding transport times, waiting times and adherence to schedules allowed faults caused by typographical errors in the input data or logical errors to be revealed, for instance the errors caused by incorrectly connected transport routes were examined. Further abnormalities, for instance regarding the number, capacity and utilisation of vehicles, transport schedules and demand, were revealed by the discussions with the experts. Via several iterative processes, the simulation model was adapted to the real system behaviour.

The validation process is illustrated by an example. The utilisation and amount of trans-

¹⁵⁶ Illustration with adaptations according to Robinson et al. (2010), p.386.

¹⁵⁷ cf. Rabe et al. (2008), p.113.

¹⁵⁸ cf. Ibid., p.97.

¹⁵⁹ cf. Ibid., p.112, Balci (1998), p.356.

port showed significant differences between the simulation results and reality. The discussions with the experts showed that the so-called ‘squeeze’ factor was the reason for the deviation. At this point, the capacity of transport vehicles in the simulation was set to a certain default maximum number of pallet spaces.¹⁶⁰ As soon as 100% capacity utilisation was reached at the loading, the simulation model initiated a second ‘additional’ transport. However, in reality, a certain number of pallets can be piled. The experts proved that for internal transport planning, 130% capacity is assumed because of this squeeze factor. The simulation was adapted to this finding. This significantly reduced the number of additional transport processes. Furthermore, the capacity utilisation is reported up to a maximum level of 130%.

The accomplished triangulation of validation and verification methods balanced the specific disadvantages of the individual validation and verification techniques. They were enhanced by a sensitivity analysis.

Sensitivity Analysis

A sensitivity analysis was performed to prove the functionality of the developed simulation model for extreme high and low demand situations. The analysis shows that the simulation model worked well with very low demand quantities. However, for very high demand situations with more than 50% of the ‘normal’ demand, the simulation reached its limits. The reasons for this were the capacity restrictions that resulted from the model design.

In accordance with the real system, primary and additional transport vehicles were modelled for each transport route. For extremely high demand situations, not only the primary, but also some additional transport vehicles are used to the full. As a result, prioritised goods were not picked up for delivery to the store on the day of generation. In reality, this would not be acceptable: in these ‘extreme’ situations (see previous chapter), a third transport resource would be activated. However, in the simulation model, this system behaviour was not designated.¹⁶¹

¹⁶⁰ Typically 33 pallets per truck.

¹⁶¹ One reason for this decision was that in freight transport, capacities are not usually defined according to peak loads. See, for instance, Bendul (2009), p.177;

5.6 Step 4: Experimental Plan and Setup of Experiments

This section describes the experimental plan and the setup of the simulation runs. The initial values for the simulation objects, the simulation duration and the experimental plan are defined. The initial values and the framework conditions of a simulation run significantly influence the simulation results. They were held as constant for all the simulation runs conducted to allow mutual comparability.

Initial Values and Stabilisation Period

For the simulation study, it was assumed that at the beginning of the simulation all the resources (vehicles, ramps and stores) were idle and all queues were empty. This corresponds to the real system because at the weekends there are usually no waiting orders. The simulation started with the generation of defined amounts of goods at defined time points and DCs. Since all resources were idle at the beginning of the simulation run, no stabilisation period was required.¹⁶²

Simulation Step and Simulation Duration

The time step was one second to ensure an adequate level of accuracy for the measurement of the adherence to schedules and the lead times.

There were different demand values for the five weekdays. Since no further temporal fluctuation was considered in the model, the accomplishment of a one-week simulation run was sufficient.

Each simulation run included 1 week (604800 seconds). Bottlenecks or overcapacities were able to be observed in this time span. Four different demand situations were modelled to gain sufficient knowledge on the system behaviour for fluctuating demands.

Experimental Plan

The simulation study was accomplished on the basis of a predefined experimental plan. This plan avoided a research process that was guided by specific results and may have excluded important factor combinations from the analysis.

The scenarios presented in section 5.3 were the bases of the experimental plan. The basic scenario modelled the as-is state of the SC concept. Four simulation runs were accom-

¹⁶² This means that there were no relevant fluctuations of values at the beginning of the simulation run.

plished for the four scenarios, each for a different demand situation: (1) -20% demand quantity, (2) normal demand, (3) +20% demand quantity and (4) +50% demand quantity. In total, 16 simulation runs were accomplished. CT scenario I included rail transport for the main haulage between the DC and the first store without any adaptations of the SC concept. For each adaptation of the SC concept, a separate simulation model needed to be configured.¹⁶³ CT scenario II was equal to CT scenario I, but contained adaptations to the production concept. CT scenario III was also equal to CT I but contained adaptations to the distribution concept. The specific adaptations were derived from the analysis of the basic and CT scenario I. The details are discussed directly before the discussion of simulation results (cf. section 5.7.3 and section 5.7.4). Table 5 - 8 summarises the experimental plan

simulation scenario	description
1 - basic scenario	as-is state
2 – CT scenario I	as-is SC configuration with integrated CT
3 – CT scenario II	CT scenario I with adaptations to the production concept
4 - CT scenario III	CT scenario I with adaptations to the distribution concept

Table 5 - 8: Experimental plan for the simulation study.

Based on the experimental plan, 16 simulation runs were accomplished. The specific setup and results of the different simulation runs are discussed in the following section.

5.7 Step 5: Description and Analysis of Simulation Results

Introduction This section specifies the setup and discusses the results of the different simulation runs. The section is ordered according to the four different simulation scenarios introduced in the previous section. The full documentation of simulation results can be found in Appendix D.

5.7.1 Basic Scenario – Modelling the ‘as-is’ Situation

Introduction The basic scenario modelled the as-is situation of *Manor*’s distribution network as introduced above. It includes eleven stores and two DCs. Sites are connected by 12 different transport routes. The transport routes are operated by primary and – if the capacity is used to the full – additional vehicles. The results of the basic scenario can be understood as a ‘*benchmark*’ for the evaluation of the following CT scenarios.

¹⁶³ Axelrod (2005), p. 8.

Utilisation of Transport Vehicles – Basic Scenario

Figure 5 - 12 and Figure 5 - 13 show the results of the transport vehicle utilisation analyses in the basic scenario. The illustrations show the average utilisation per weekday and transport route. The average utilisation of primary transport vehicles was 73% for the normal demand situation; for the additional transport vehicles, it was 61%.

The illustration shows that the utilisation strongly varied from store to store. Missing values mean that there was no transport scheduled for that specific weekday. The analysis shows that the transport routes H 220, H 70 and M 2 were regularly used to the full (here 130%). The reason for the strongly differing utilisation levels was the different demand levels for the different stores. For instance, route M 1 is used to deliver to the stores in Geneva and Vésenaz. Geneva is the biggest *Manor* store in Switzerland. Thus, the demand in pallet equivalents is much bigger in comparison with the amount of pallet equivalents on the transport route H 75, which only delivers goods to the Monthey store, a medium-sized store with comparably low demand. Furthermore, the maximum capacity influences the utilisation. For instance, transport route M 24 relies on a truck with a maximum capacity of 17 pallets (+30% squeeze factor), whereas most other routes are served by trucks with 30 and more pallet spaces (+30% squeeze factor).

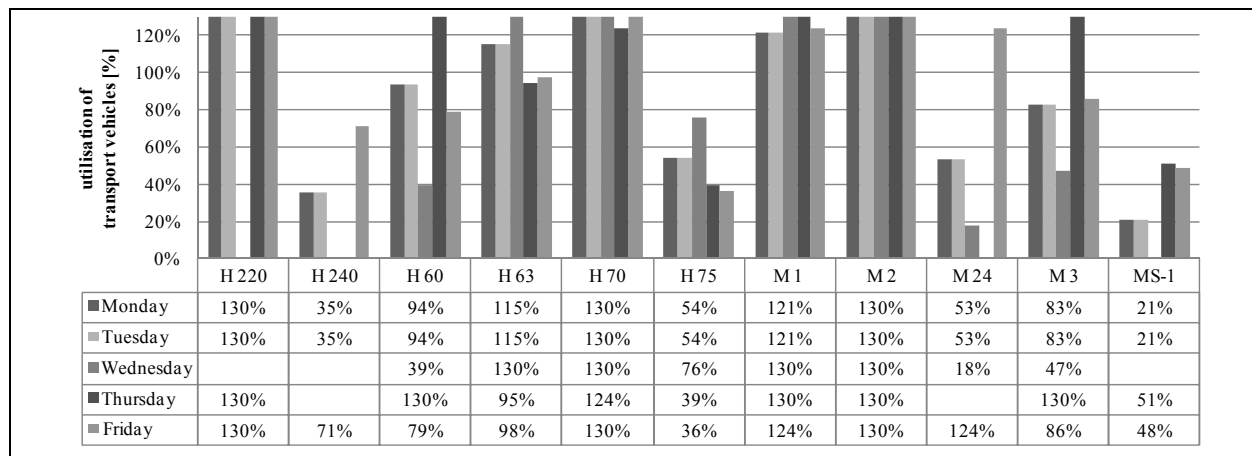


Figure 5 - 12: Mean utilisation per primary transport route and weekday for the normal demand situation.

As a result of the high capacity utilisation of the primary transport, additional transport was accomplished. The utilisation of the additional transport vehicles was comparably low. Figure 5 - 13 illustrates the mean utilisation of the additional transport processes. Transport route H 240 is not included, since for this transport no additional transports were accomplished.

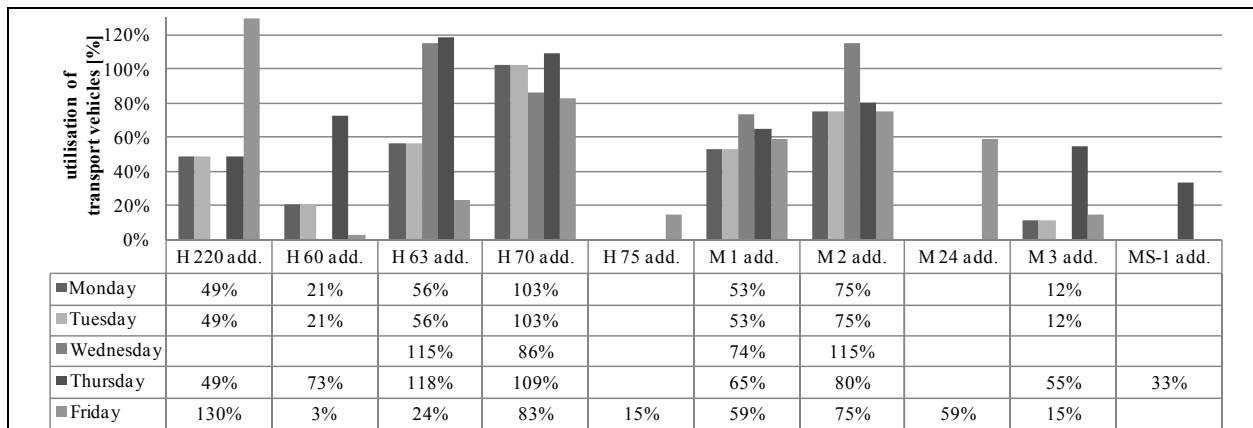


Figure 5 - 13: Mean utilisation per additional transport route and weekday for the normal demand situation.

In general, non-scheduled transport causes non-linear additional costs. They require additional planning efforts and road carriers charge an increased price for holding the necessary capacities available.¹⁶⁴ Thus, in for *Manor* a small number of additional transport vehicles is sought. Nevertheless, high utilisation is worthwhile.

Although the thesis in hand did not aim to optimise the as-is distribution concept, this comparably high utilisation of primary transport indicates that there are no capacities to intercept fluctuations in demand without additional transport. Here, a general adaptation of transport routes may be sensible to improve the utilisation considering the number and utilisation of additional transport processes, as well as the required flexibility to deal with fluctuating demands.

The simulation runs with the increased demand situations (illustrated in Figure 5 - 14) prove this. For the 50% increased demand situation, additional transport was required on all transport routes.

¹⁶⁴ Corsten et al. (1992), pp. 180; Stuhlmann (2000).

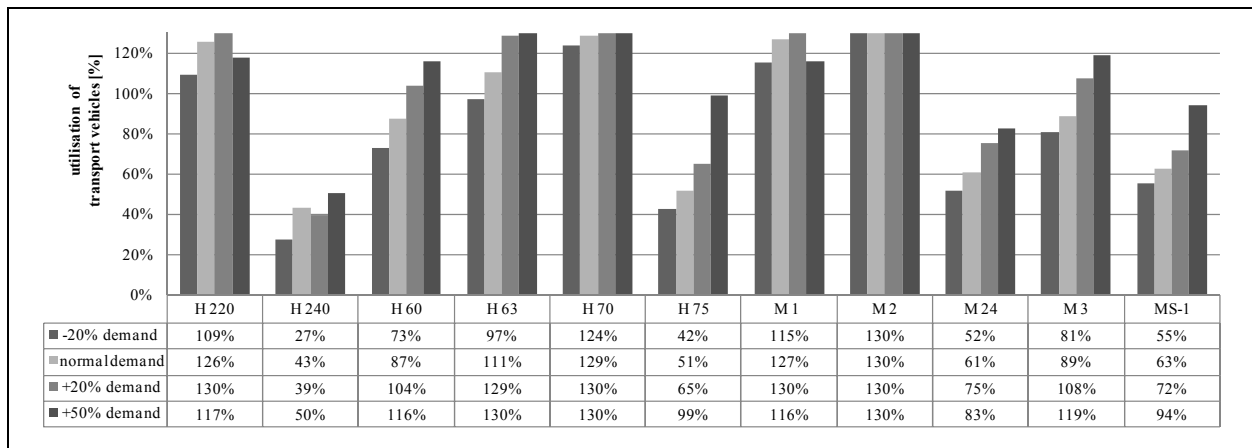


Figure 5 - 14: Average utilisation of primary transport vehicles for different transport routes and demand situations.

Figure 5 - 15 shows the average utilisation of the additional transport routes for the different demand situations. The illustration shows that for a 50% increase in demand quantity, the transport routes H 70 and M 2 were again used to the full. This means that eventually a third transport vehicle would be required if no adaptations to the transport route planning were made.¹⁶⁵

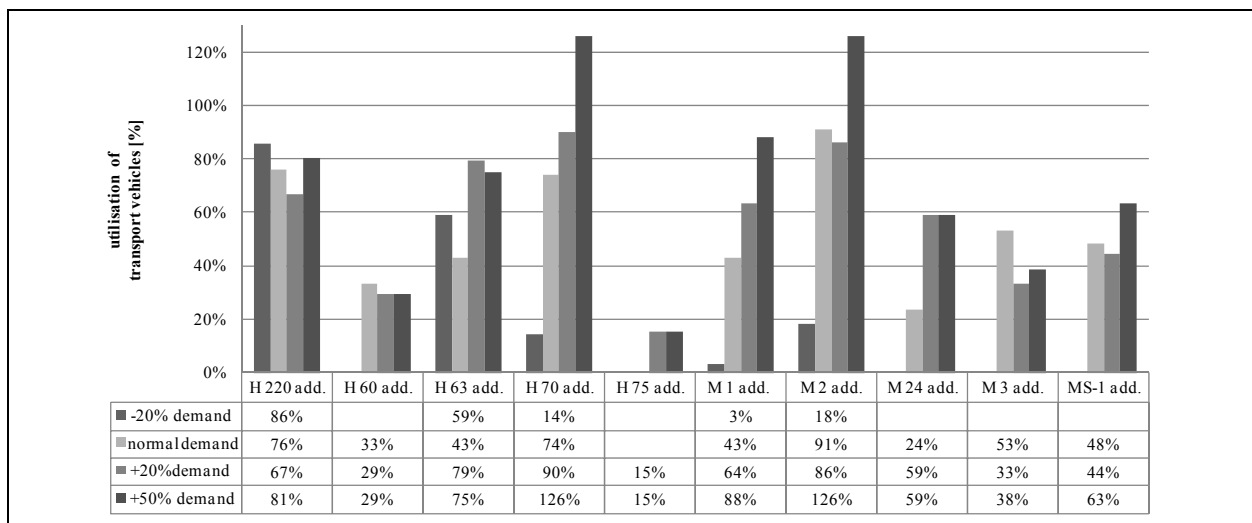


Figure 5 - 15: Average utilisation of primary transport vehicles for different transport routes and demand situations.

Order Lead Time – Basic Scenario

The order lead time is critical in a lean SC with continuous replenishment processes. A short lead time allows a high level of product availability in the stores and directly impacts

¹⁶⁵ For example the change from a milk-run concept to direct concept (cf. section 3.3.1, for different types of transport concepts).

the capital commitment costs. Thus, a reduction of lead time is generally desirable as long as the product quality and delivery service are not jeopardised.

Figure 5 - 16 and Figure 5 - 17 illustrate the lead time elements per store and DC. The illustrations show that the share of waiting time was comparably high for the stores in Sion and Sierre. The reason was that deliveries to these have recently been made via the regional cross-docking platform in Sion. Thus, the goods are taken from DC Hochdorf via single wagon freight transport to the PF Sion and then by truck to the stores. The goods arrive at stores comparably late in the evening. For all other stores, road transport is the main contributor to the lead time. Depending on the average number of pallets per transport, the handling time varied between 0.58 h for the Yverdon store with a small average number of transported goods and 1.39 h for the Vézenaz store with a very high average number of transported goods.

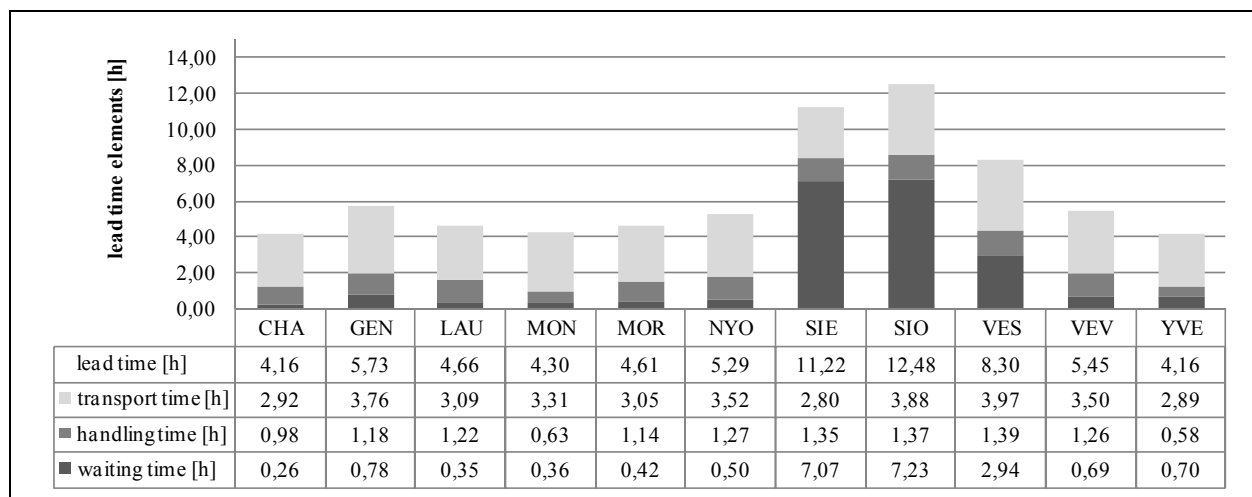


Figure 5 - 16: Transport time elements per store for DC Hochdorf.

Figure 5 - 17 shows that the share of waiting times was distinctively higher for DC Möhlin. The goods for the stores in Lausanne, Sierre, Sion, Vézenaz and Vevey were all characterised by early generation times. These are partly significantly prior to loading and departure and indicate temporal quota for CT integration. Thus, the lead times were comparably long. In particular, the waiting times elements indicate that there might be temporal quota to be opened for the CT integration.

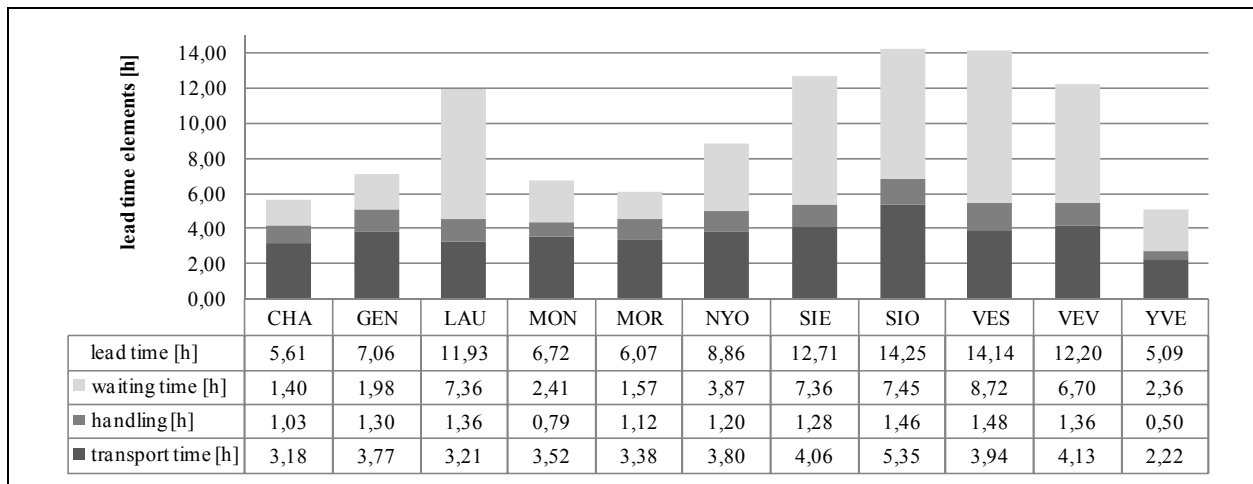


Figure 5 - 17: Transport time elements per store for DC Möhlin.

Figure 5 - 18 shows the variation of lead time elements for the four different demand situations. The illustration shows that the transport time was not significantly affected by the different transport quantities. The differences resulted from additional waiting times caused by longer waiting times prior to loading and congestion of several trucks at the unloading (only one truck at a time can be handled). Expectedly, the handling and waiting times behaved linearly to the change of demand. However, the lead times behaved in a less than proportionate way to the changed demand situation. The effect of the shortened or increased waiting times affected the total lead time only moderately.

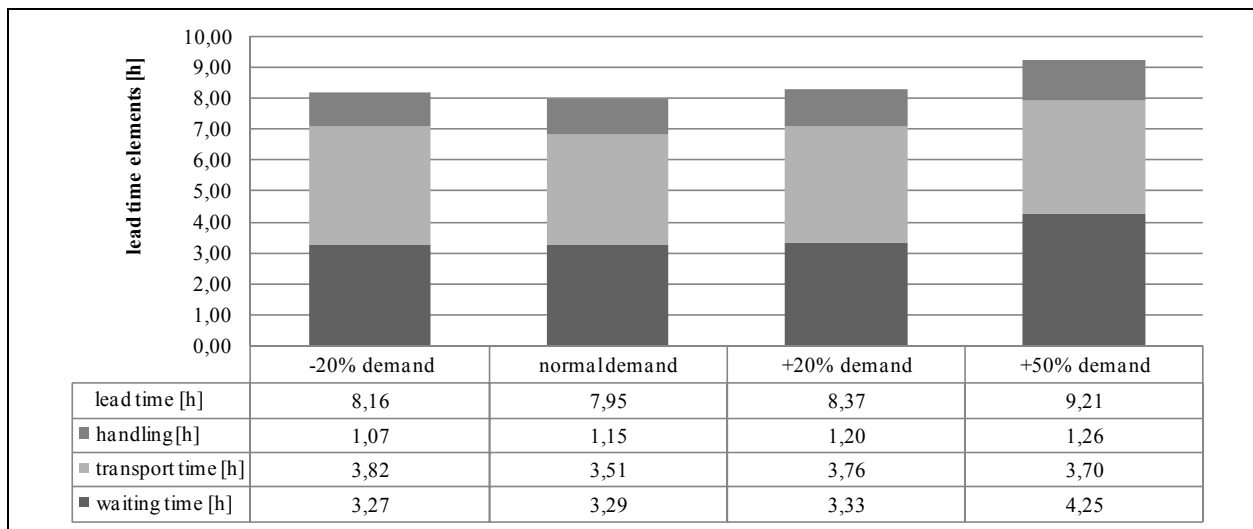


Figure 5 - 18: Average lead time elements for different demand situations.

The lead time directly influences the inventory in a system: the longer the order lead time, the higher the inventory level in the total system.

Inventory – Basic Scenario

Figure 5 - 19 visualises the average inventory level per store and DC. The inventory level depends on two main aspects: the average order lead time and the demand quantity per store. Thus, the different stores showed significantly varied inventory levels. In particular, the comparably big stores in Geneva, Lausanne and Vevey with high demands per day showed high inventory levels. Furthermore, the stores in Sierre, Sion and Vevey were characterised by high inventory levels because of their comparably long lead times (cf. basic scenario).

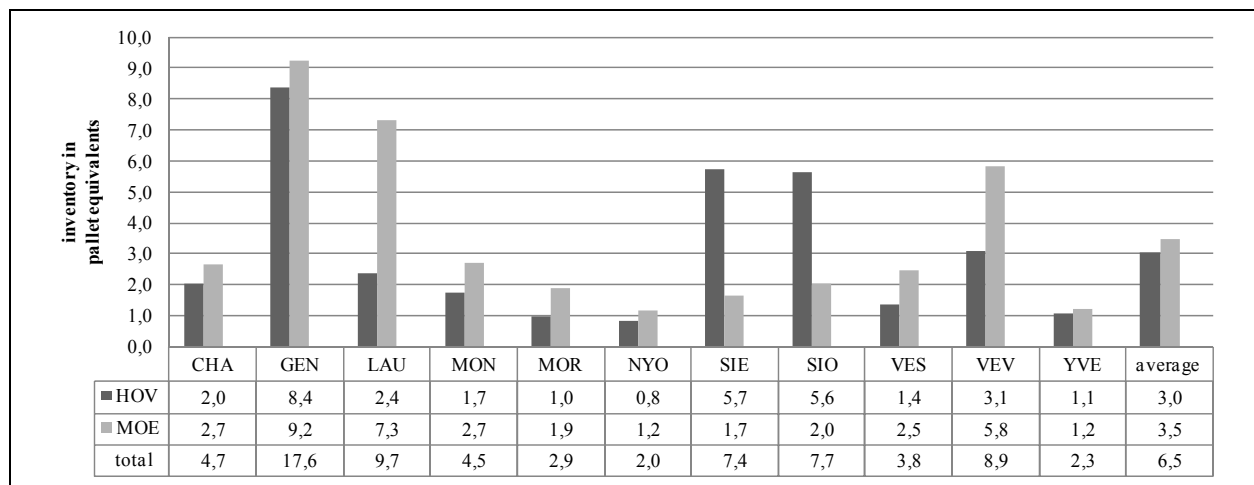


Figure 5 - 19: Average inventory in the transport between DC and the stores.

Figure 5 - 20 illustrates the average inventory level over all stores for the four different demand situations. The illustration shows that there was a less than proportionate connection between the demand quantity and the inventory level for a reduction in demand and a more than proportionate connection for an increase in demand. For the 20% reduced demand situation, an inventory reduction of 14% can be observed. For a 20% and a 50% increased demand, inventory increases of 23% and 92% can be observed. The reason for this non-linear relationship was the simultaneous change of both influencing factors. The demand and the lead time were affected by the different demand situations.

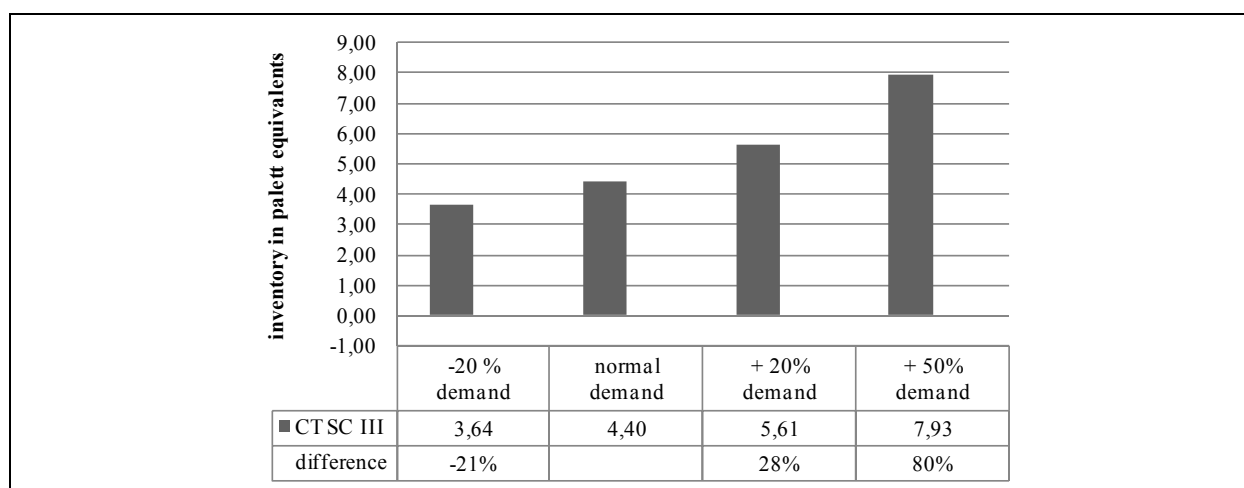


Figure 5 - 20: Average inventory for different demand situations.¹⁶⁶

Emissions – Basic Scenario

Emissions are affected by the transport distance, the street profile and the inclination profile. The example in Table 5 - 9 shows the road distance, the fuel consumption and the emissions per route segment for transport route H 60.

transport route	route segment start	route segment destination	distance [km]	fuel consumption [g]	CO ₂ [g]	NO _x [g]	particle [g]
H 60	DC HOV	CHA	207	47 610	172 892	1 758	43
	CHA	MOR	11	2 530	8 983	92	2
	MOR	NYO	27	6 210	22 325	227	6
		total	245	56 350	204 200	2 076	51

Table 5 - 9: Average emissions for transport route H 60.¹⁶⁷

Figure 5 - 21 visualises the CO₂ emissions for the different transport routes. The longer the transport routes were, the higher the CO₂ emissions were. Reductions were the smallest for transport routes that already contained rail transport (H 220 and MS 1). Here, the replacement of the road by rail distance in the simulation scenario was comparably small. The curves of fuel consumption, NO_x and particle emissions are similar to the shape of the CO₂ emissions.¹⁶⁸

¹⁶⁶ Complete table in Appendix D.

¹⁶⁷ Full analysis in Appendix D.

¹⁶⁸ Full tables in Appendix D.

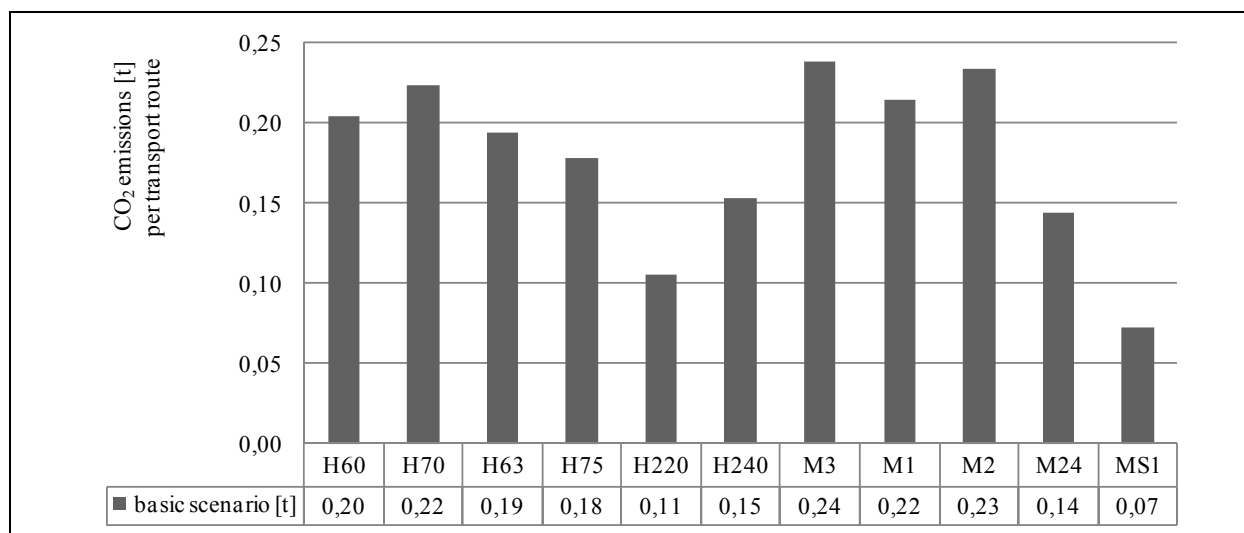


Figure 5 - 21: CO₂ emissions per transport route.

Table 5 - 10 gives an overview of the further emissions factors for one completion of the different transport routes.

route ID	distance rail /road [km]	fuel consumption [l]	CO ₂ [t]	NO _x [t]	particle [g]
H 60	0 / 245	67.9	0.204	2 076	43.1
H 70	0 / 269	74.5	0.223	2 271	55.5
H 63	0 / 234	64.8	0.194	1 978	48.4
H 75	0 / 213	59.0	0.178	1 808	44.3
H 220	213 / 34	37.7	0.106	1 582	42.3
H 240	0 / 185	51.3	0.154	1 564	38.3
M 3	0 / 284	78.7	0.238	2 420	59.5
M 1	0 / 258	71.5	0.215	2 186	53.6
M 2	0 / 280	77.6	0.234	2 376	58.3
M 24	0 / 173	47.9	0.145	1 471	36.1
M 1	88 / 0	24.4	0.072	736	17.9

Table 5 - 10: Emissions per transport route.

The emissions in the one-week simulation run depended on the emissions per transport route and the number of accomplished primary and additional transport routes. The bases were the emission profiles for each transport route, as well as the number of primary and additional transport.

Table 5 - 11 gives an overview of the emissions caused by all the transportation accomplished in the one-week simulation run.

total per year	emission	unit
fuel consumption	4.73	in 1000 L
CO ₂	13.35	in t
NO _x	140 353	in g
particles	3 473	in g
distance on road	17.06	in 1000 km

Table 5 - 11: Emissions for a one-week simulation run.

Adherence to Schedules – Basic Scenario

Adherence to schedules was measured by comparing the actual arrival time at the store and the designated delivery window.

Figure 5 - 22 shows that there was a significant difference between orders that arrived at the stores too early and those that arrived too late. In reality, a comparably low average speed of transport vehicles is assumed in route planning; in particular, for long transport distances. Delays caused by unexpected disturbances can be balanced in this manner. In cases where no delays occur, the truck driver waits near to the store until the defined delivery window is open. These deliveries can be assumed to be on time. The same principle is valid for the stores in Yverdon, Sion and Sierre. They are not included in the illustration since they all have next day delivery. Therefore, it is assumed that they are all on time.

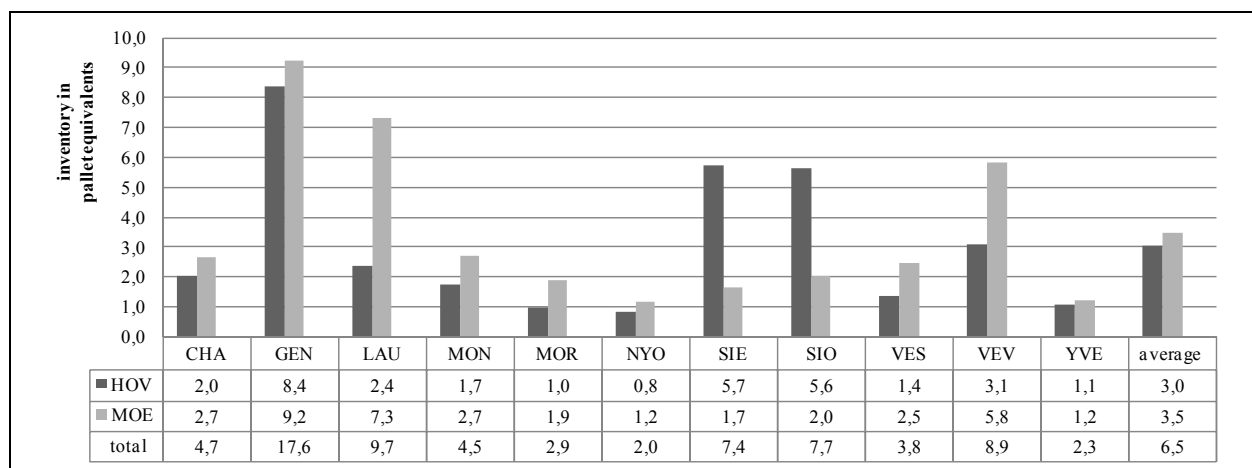


Figure 5 - 22: Average deviation and delay for different stores and DCs.

These findings are reflected in the analysis of the adherence to schedules, which set the number of too early and too late deliveries as a ratio against the total number of deliveries. Table 5 - 12 summarises the results of the adherence to schedules regarding average deviation and average delay for the different demand situations. The table shows that the adherence to schedules was best in the case of the normal demand situation. For the 20% reduced demand situation, the adherence to schedules regarding deviation was decreased. The reason is that handling times are linearly connected to demand quantity. As a result, for the reduced demand situation, the lead time was shortened and deliveries arrived prior to the defined delivery windows. The decreased adherence to schedules regarding the delay was caused by the reduction in additional transport. The amount of transport with low utilisation and short handling times was reduced and thus the share of non-delayed transport was reduced. For the increased demand situation, the adherence to schedules regarding delays was reduced to 82%, 76% and 88% for the +/-30 minute delivery windows. The

reason for this decrease was the enhancement of lead times. However, the effect of demand increases on the adherence to schedules appears to be less than proportionate. Obviously, the enhanced delivery windows positively influenced this, too. This indicates that enhanced delivery windows positively impact adherence to schedules in general and thus, may also support the CT integration, which causes enhanced lead times.

demand situation	-20% demand		normal demand		+20% demand		+50% demand	
	+/-15 min	+/- 30 min	+/-15 min	+/- 30 min	+/-15 min	+/- 30 min	+/-15 min	+/- 30 min
adherence to schedules regarding deviations (too late and too early deliveries)	41%	54%	42%	62%	36%	56%	40%	40%
adherence to schedules regarding delays (too early deliveries)	88%	94%	95%	99%	82%	88%	76%	88%
mean deviation [h]	0.54		0.49		0.50		0.45	
mean delay [h]	0.09		0.03		0.12		0.17	

Table 5 - 12: Overview of key figures regarding the adherence to schedules for the basic scenario.

Transition The presented results served as the bases for the evaluations of the CT scenarios introduced in the following sections.

5.7.2 CT Scenario I - Integration without Adaptation to the SC Concept

Introduction CT scenario I included identical sites to the basic scenario: eleven stores and two DCs, enhanced by two terminals (cf. section 5.3.3). Accordingly, the transport routes were enhanced. Namely, all '*long-distance*' relations between DCs and the first store on the transport route were altered.¹⁶⁹ The original first route segment (transport from DC to the first store) was replaced by three different route segments: (1) the transport from the DC to the terminal in Härkingen, (2) the rail transport from Härkingen terminal to Daillens terminal and (3) the transport from Daillens terminal to the first store on the transport route. The subsequent route segments remained identical to the basic scenario. According to this, all the transport routes presented in Table 5 - 6 were replaced and renamed. Table 5 - 13 shows an extract of the list (for the full see Appendix D).

¹⁶⁹ Transport routes MS-1 and H 220 were excepted because they are accomplished by single wagon freight transport.

route ID	route segment	start	destination	transport resource	transport time [sec]	start time
H 60 CT	30	DC HOV	T HAE	V I	3 120	11:30 AM
		T HAE	T DAI		*	
		T DAI	CHA		780	
	125	CHA	MOR		900	
	175	MOR	NYO		1 500	
H 70 CT	31	DC HOV	T HAE	VII	3 120	11:00 AM
		T HAE	T DAI		*	
		T DAI	GEN		960	
	141	GEN	VES		1 200	
H 63 CT	32	DC HOV	T HAE	V III	3 120	11:00 AM
		T HAE	T DAI		*	
		T DAI	LAU		960	
	154	LAU	VEV		27 000	
H 75 CT	33	DC HOV	T HAE	V IV	3 120	12:30 AM
		T HAE	T DAI		*	
		T DAI	MON		3 300	

*For train transport times see Table 5 - 14

Table 5 - 13: Extract of route plan for the CT scenario I (complete information in Appendix D).¹⁷⁰

Furthermore, the train schedule between Härkingen terminal and Daillens terminal was integrated into the simulation model. It determines the rail transport times, which differ for the distinct trains. In total, there are eight trains a day from Härkingen terminal to Daillens terminal. Table 5 - 17 shows the different trains' start and transport times. According to the expert interviews, the maximum capacities of the trains are set to ten truck shipments (independent from the utilisation of the truck). The trains are termed with either a sequence of numbers or with specific names.

train ID	name	transport time [sec]	start time	arrival time	capacity [truck shipments]
T 1	Mistral	5 460	11:38 AM	1:43PM	10
T 2	50727	6 840	2:41 PM	4:31PM	10
T 3	50735	6 540	7:34 PM	9:33PM	10
T 4	50740	6 660	8:40 PM	10:27PM	10
T 5	50738	6 300	11:14 PM	01:04 AM	10
T 6	50392	8 220	00:52 AM	02:38 AM	10
T 7	Bluehope	7 260	02:36 AM	04:09 AM	10
T 8	50708	6 420	03:36 AM	04:39 AM	10

Table 5 - 14: Train schedule between Härkingen terminal and Daillens terminal.

Depending on the specific arrival times at the terminal, shipments are conveyed by the next available train. Therefore, trucks must arrive at the terminal at least 30 minutes prior departure. After the train arrives at the destination terminal, 30 minutes are required for transshipment and overhead before the trucks can leave the terminal for store delivery. To

¹⁷⁰ For complete information on transport routes, transport times and start times, see Appendix D.

simplify the simulation model, it was assumed that the entire truck was transported. Thus, no additional trucks for the ongoing haulage had to be modelled. For the interpretation of results, it was taken into consideration that, in reality, two trucks are necessary, one for the pre-haulage (DC to start terminal) and one for the ongoing haulage (destination terminal to store(s)). Since truck loading is identical for pre- and ongoing-haulage, this simplification did not affect the validity of the simulation results.

Utilisation of Transport Vehicles – CT Scenario I

There was no difference between the utilisation of trucks in the basic scenario and in CT scenario I. The reason was that the transport routes and demand quantity were not been altered. Thus, no additional analysis of utilisation was performed in this section. However, the eventual discussion in the following section contains qualitative considerations of the impact of CT integration, which could not be modelled by the simulation model used.

Nevertheless, the utilisation of the different trains was analysed. Figure 5 - 23 shows that for all the transport, only three different trains were used: T1 - the so-called Mistral train that leaves Härkingen terminal at 11:38 AM; T2 - train no. 50727 that leaves Härkingen terminal at 2:41 PM; and T3 - train no. 50735 that leaves Härkingen terminal at 7:34 PM. The reason for this clustering in the daytime is that all the transport vehicles leave the DCs in the morning or afternoon and reach the trains during the day and in the early evening. The different demand situations did not significantly impact the utilisation of train T1. For train T2, increased demand was reflected by increased utilisation. The number of shipments on train T3 was not increased for the increased demand situations because the capacity of the earlier train T2 did not reach its maximum. Thus, only a single shipment was made, which in most cases reached the terminal after the departure of train T3.

Figure 5 - 23 shows that on no weekday nor for any demand situation were the train capacities maximised. This means that additional waiting times at the Härkingen terminal caused by occupied trains can be excluded from CT scenario I.

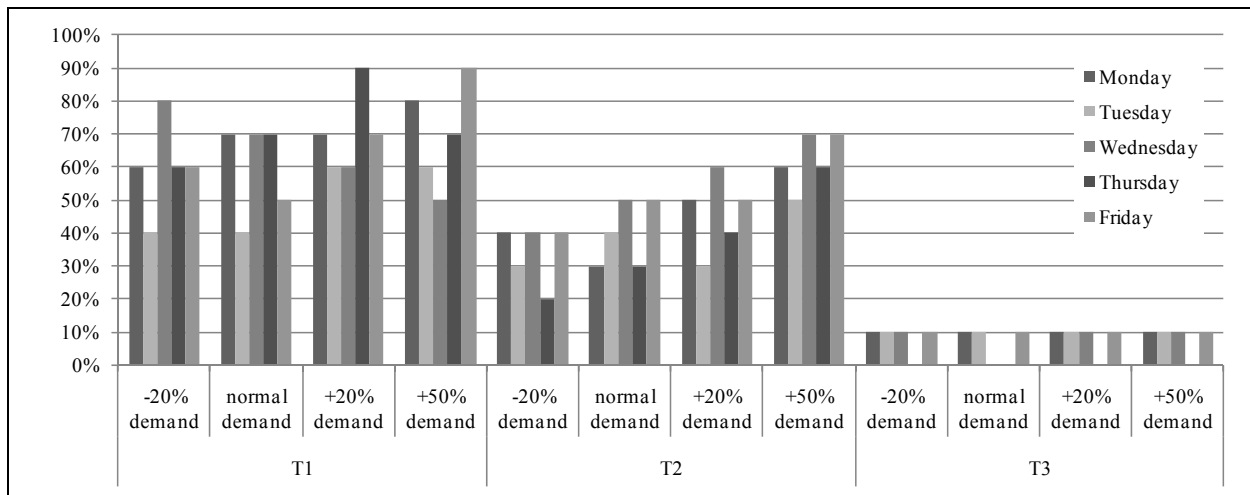


Figure 5 - 23: Utilisation of trains for CT scenario I.

Order Lead Time – CT Scenario I

The introduction of additional transshipment processes, rail transport and the resulting changes to the transport routes significantly affected the order lead time and the share of transport, handling and waiting times. Figure 5 - 24 and Figure 5 - 25 illustrate the lead time elements for CT scenario I for the different stores and DCs. The illustration shows that the handling times in particular were affected by the integration of CT. The additional transshipment process caused an increase in the handling time per transport route of one hour.

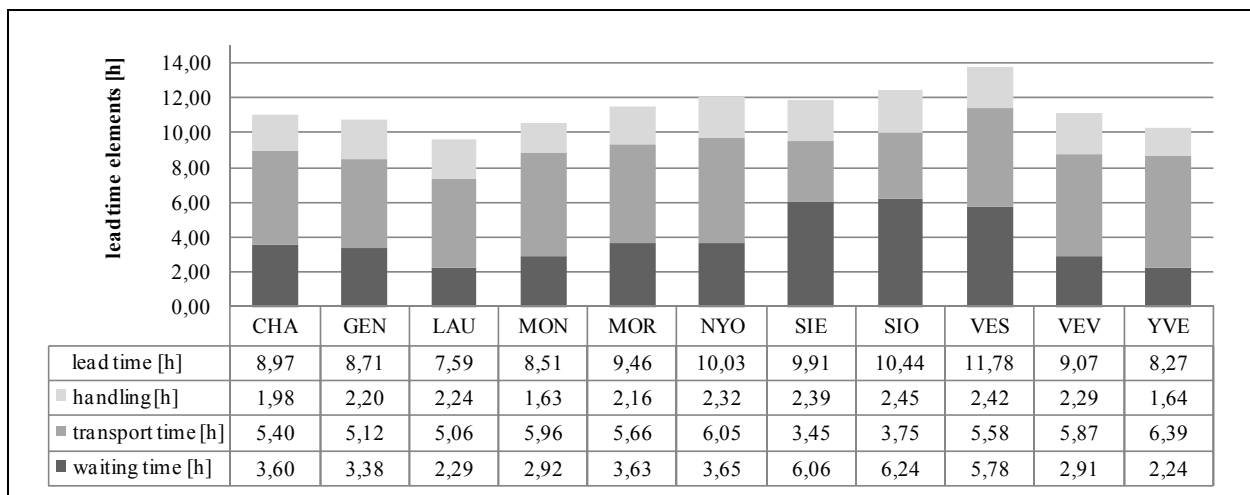


Figure 5 - 24: Transport time elements per store for DC Hochdorf for CT scenario I and the normal demand situation.

As for the basic scenario the share of lead time elements is slightly different for goods coming from DC Möhlin caused by different product generation times and departure times, different transport durations as well as different delivery windows and demand quantities.

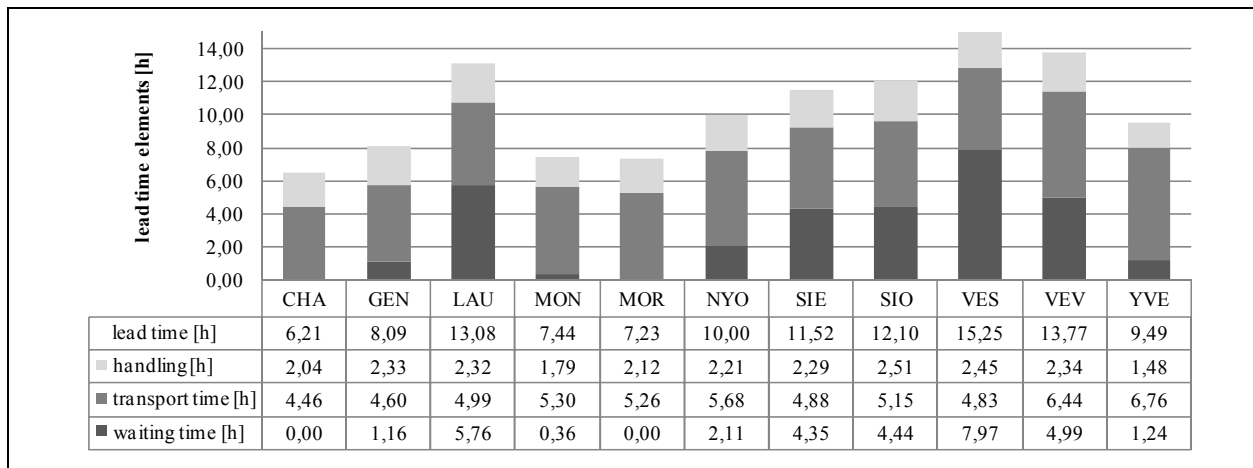


Figure 5 - 25: Transport time elements per store for DC Möhlin for CT scenario I and the normal demand situation.

Figure 5 - 26 contrasts lead time elements for CT scenario I and the basic scenario. The main part of the overall lead time increase of 24% can be explained by the increase in handling time of 89% and the transport time by 51%. However, waiting time was decreased by 24% with CT integration. The increased level of handling times was a result of the additional transshipment processes at the terminals. The reduction in waiting times can be explained by the replacement of additional transport and handling times. Nevertheless, the share of waiting times was still 25% of the entire lead time. Thus, the analysis indicates that waiting times can be used as initial points to improve the time-related aspects of CT integration into the SC concept.

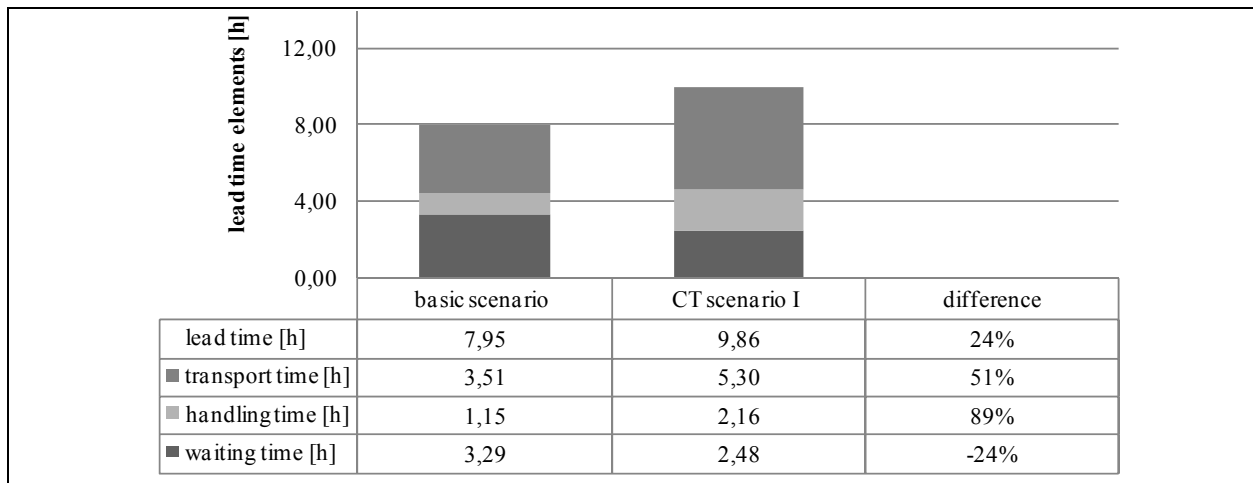


Figure 5 - 26: Comparison between average lead time elements between basic and CT scenario I.

Figure 5 - 27 contrasts the average lead times of the CT scenario I and the basic scenario for different demand situations. The comparison shows that the impact on lead times is most significant for the normal and the 20% increased demand situations. This corresponds with the findings on the non-linear relationship between demand and lead time.

This finding indicates that CT integration for higher demand levels does not necessarily affect lead times in a linear way.

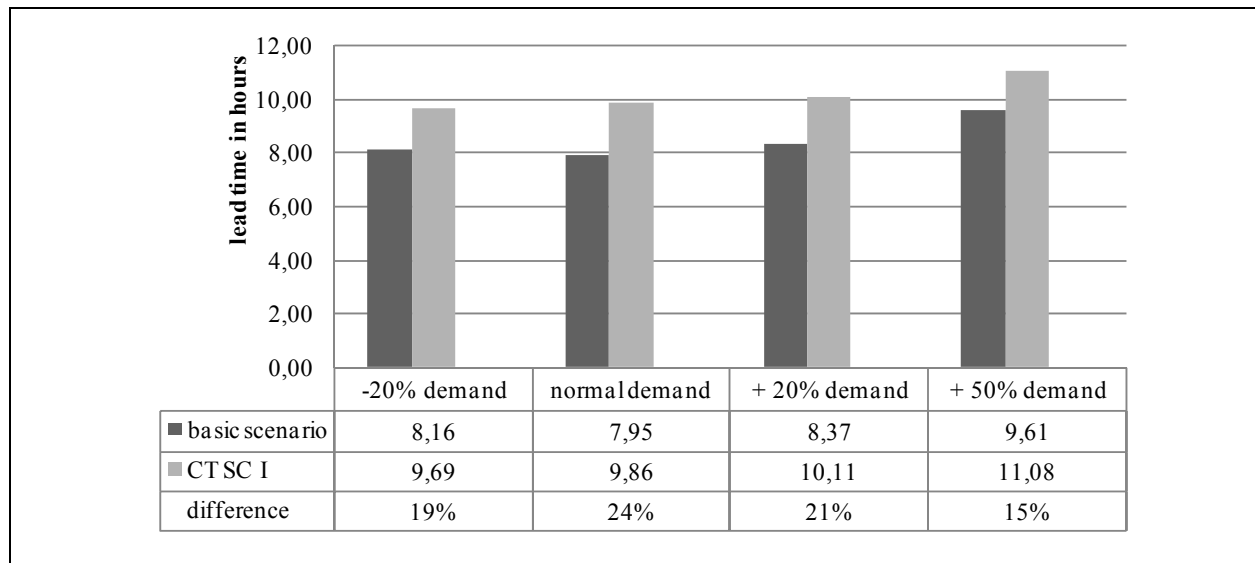


Figure 5 - 27: Lead time comparison of basic and CT scenario I for different demand levels.

Inventory – CT Scenario I

The inventory levels in CT scenario I were significantly increased in comparison with the basic scenario. Since the input data of the average demand per store and weekday was not altered, the reason for this increase was the enhancement of order lead times and the changes in the durations of certain inventory levels.

Figure 5 - 28 illustrates the different inventory levels per store for CT scenario I in comparison with the basic scenario for the normal demand situation. The total average inventory for all stores was increased by 21%. There is a difference between the increase in order lead time and the increase of inventory, because the relation is – due to the calculation of the integral of the temporal inventory course – not linear (cf. section 5.3.4).

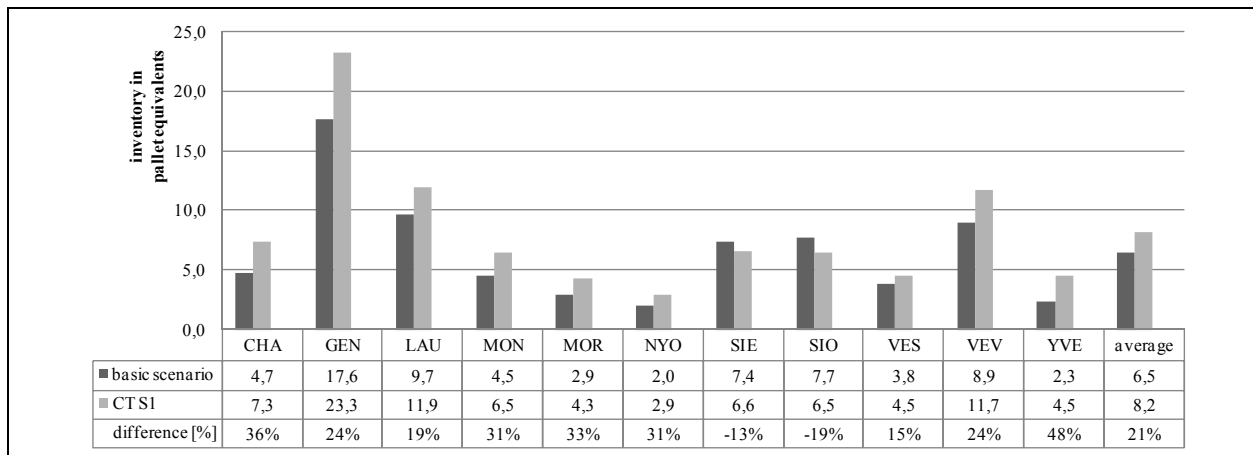


Figure 5 - 28: Comparison of inventory levels per store for CT scenario I and the basic scenario.¹⁷¹

Figure 5 - 29 illustrates the inventory times for the different demand levels. The analysis shows that the non-linear connection between demand and inventory level is also valid for CT scenario I. The reduction in demand of 20% caused a reduction in inventory of 18%. The demand increases of 20% and 50% increased the inventory levels by 28% and 87%. The reason for this was the effect of changed demand quantities reinforced by the resulting longer lead times.

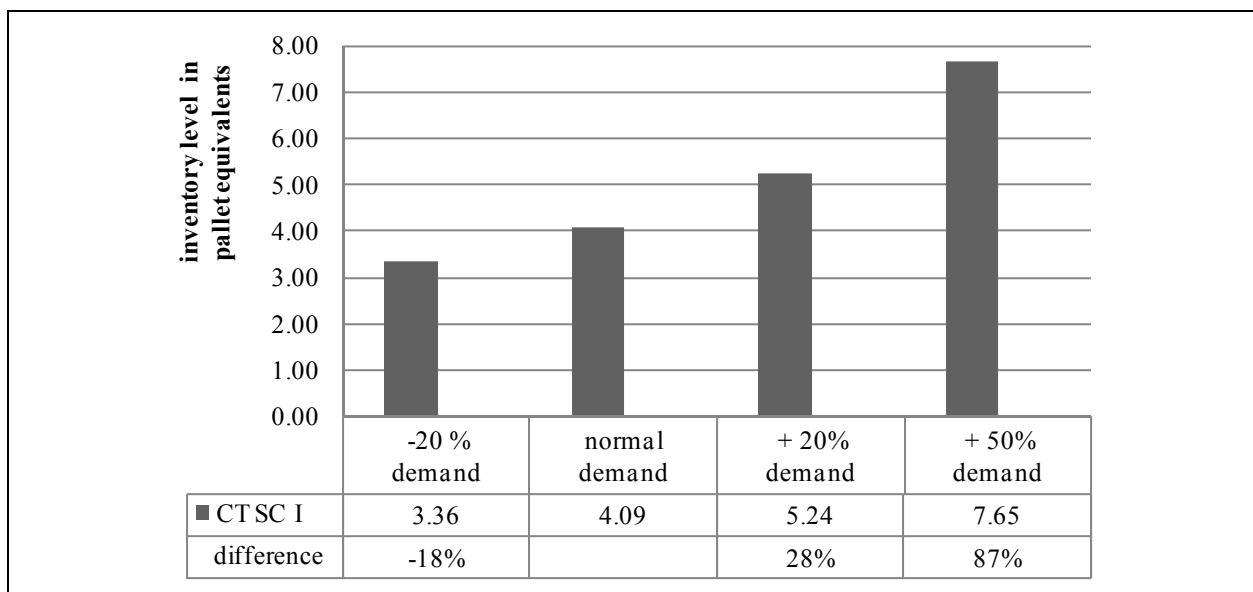


Figure 5 - 29: Comparison of inventory levels for CT scenario I for the different demand situations.

¹⁷¹ The inventory levels for the DC Möhlin change correspondingly. Full data can be found in Appendix D.

Emissions – CT Scenario I

In comparison with the basic scenario, the introduction of CT caused a significant reduction in emissions. The reason for the reduction was the replacement of road transport distances with rail transport. Table 5 - 15 illustrates this effect with the example of transport route H 60. The first route segment from DC Hochdorf to the first store was replaced by two shorter road route segments and one rail route segment. As a result, the road distance was reduced from 245 km to 105 km and 124 km by rail was integrated into the route. In total, the emissions per transport route completion were significantly reduced.

route	start position	target position	distance [km] road / rail	fuel consumption [g]	CO ₂ [g]	NO _x [g]	particle [g]
H 60	DC HOV	T HAE	53	12 190	43 087	439	11
	T HAE	T DAI	124	28 520	29 419	544	15
	T DAI	CHA	14	3 220	11 512	117	3
	CHA	MOR	11	2 530	8 983	92	2
	MOR	NYO	27	6 210	22 325	227	6
total			105/ 124	52 670	115 327	1 419	36

Table 5 - 15: Comparison of emissions for transport route H 60 for CT scenario I.¹⁷²

Figure 5 - 30 visualises the reductions in CO₂ emissions for different transport routes. Emissions were reduced for all transport routes except MS 1 and H 220, where the reduction had been already accomplished by rail transport in the basic scenario and so were thus not altered. The smallest reduction can be observed for H 240. The reason was that on this comparably short transport route, the total distance by road could only be decreased from 185 km in total to 112 km in CT scenario I. Additionally, 124 km by rail transport needed to be considered in the emissions calculation, which counteracted the positive effect. The comparison shows that savings were biggest for the transport routes H 70 (-60%) and M 1 (-63%). On these routes, the highest share of road kilometres was saved by CT integration.

¹⁷² Full analysis in Appendix D.

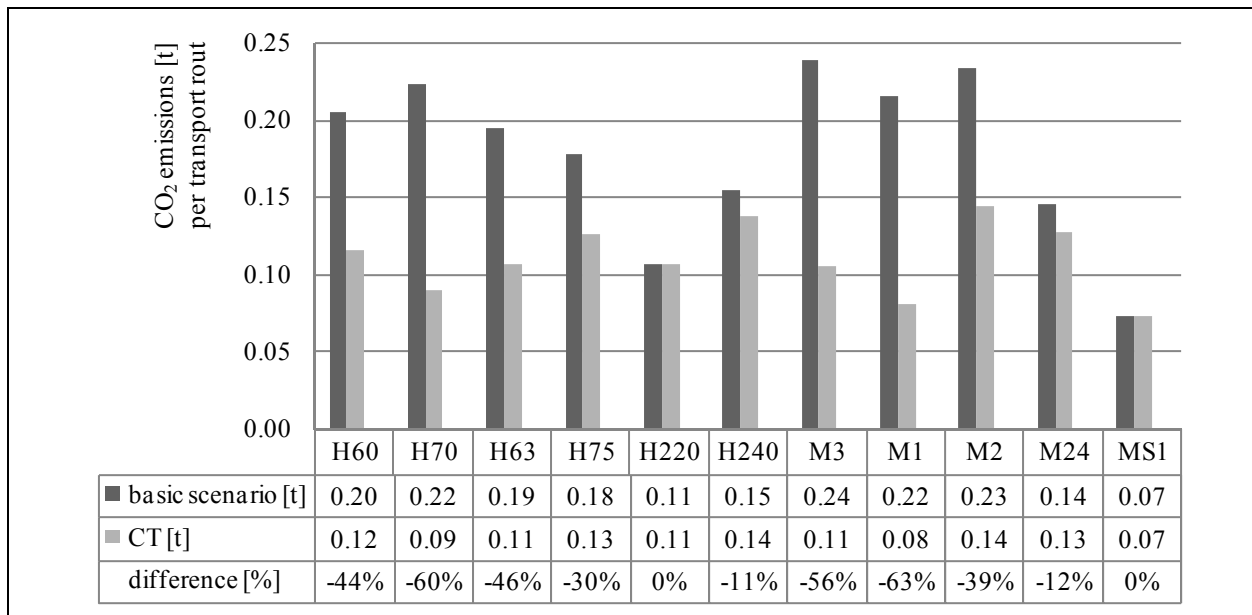


Figure 5 - 30: CO₂ emissions per transport route – comparison of basic scenario and CT scenarios.¹⁷³

Table 5 -16 summarises the key emissions figures in comparison with the basic scenario for a one-week simulation run. The table shows the absolute and the relative improvement of emissions with the CT integration.

emission factor	as-is	CT	possible savings per week	unit	improvement [%]
fuel consumption	4.73	3.02	-1.71	in 1000 L	-36%
CO ₂	13.35	7.29	-6.06	in t	-45%
NO _x	140,353	82,835	-57 518	in g	-41%
particle	3,473	2,074	-1 399	in g	-40%
distance road	17.06	9.85	-7.21	in 1000 km	-42%

Table 5 - 16: Emissions for CT scenario I in comparison with the basic scenario - calculation of possible savings for a one-week simulation run.

Adherence to Schedules – CT Scenario I

The integration of CT into the SC concept significantly increased the order lead time. As a result, the adherence to schedules was negatively affected. Figure 5 - 31 visualises adherence to schedules regarding the deviation and the delay for CT scenario I. In contradiction to the basic scenario, only a small difference between deviation and delay can be observed. The reason was that the CT integration caused a significant enhancement of lead times and thus delays in the majority of the deliveries. Thus, there is only a small differ-

¹⁷³ The curves for the further emission factors show similar curves. cf. Appendix D.

ence between the key figures measuring deviated (too early and too late) and delayed (too late) deliveries.¹⁷⁴

Different product generation and departure times were the reasons that deliveries from DC Möhlin were delayed much less than deliveries from DC Hochdorf. In DC Möhlin, product generation takes place early in the morning (cf. Table 5 - 7). For the CT integration, this means that most of the transport coming from DC Möhlin catches the train leaving Härkingen in the morning (Mistral, 11:38 AM). Thus, adherence to the delivery windows in the afternoon is better in comparison with DC Hochdorf. The product generation and departure of trucks in DC Hochdorf occur later in the morning and in the afternoon. Trucks leave DC Hochdorf distinctively later and thus catch trains leaving Härkingen terminal in the afternoon. For the basic scenario, the late departure was sufficient to meet the designated delivery windows. However, in CT scenario I, additional transshipment times, waiting times at the terminal and additional transport times caused the deliveries to be significantly delayed.

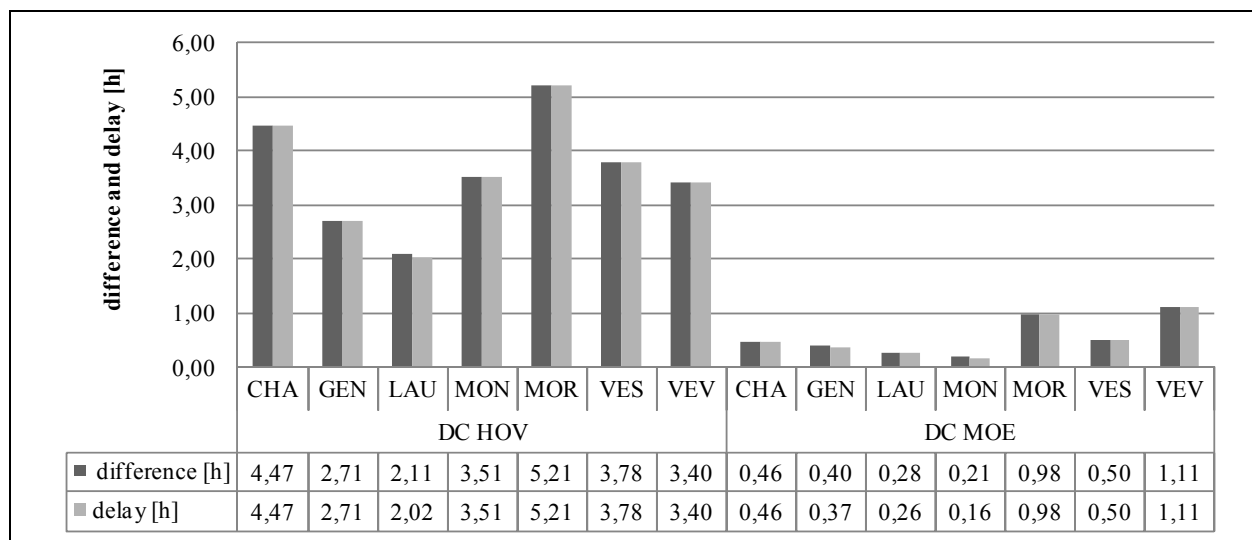


Figure 5 - 31: Deviation and delay of deliveries per store and DC for CT scenario I.

¹⁷⁴

For DC Hochdorf, the average deviation was 3.6 h and the average delay was 3.59 h. For DC Möhlin, the average deviation was 0.56 h and the average delay was 0.55 h.

Figure 5 - 32 transfers these findings for the calculation of the adherence to schedules for different demand situations. The illustration shows that the adherence to schedules for the normal demand situation was reduced from 95% and 99% to 28% and 39% for the two different delivery window sizes. The analysis shows that for the increased demand levels, the adherence to schedules was reduced even more significantly. For the 20% increased demand situation, the adherence to schedules was reduced to 28% and 32%; for the 50% increased demand situation, it was reduced to 0% and 55%. The level of 55% adherence for the +/-30 minute delivery window can be explained by the increased number of additional transport vehicles. This additional transport was characterised by comparably low utilisation and short lead times. This effect positively influenced the average adherence to schedules. This explanation is also valid for the reduced demand situation. Here, the adherence to schedules was reduced to 41% and 58%.

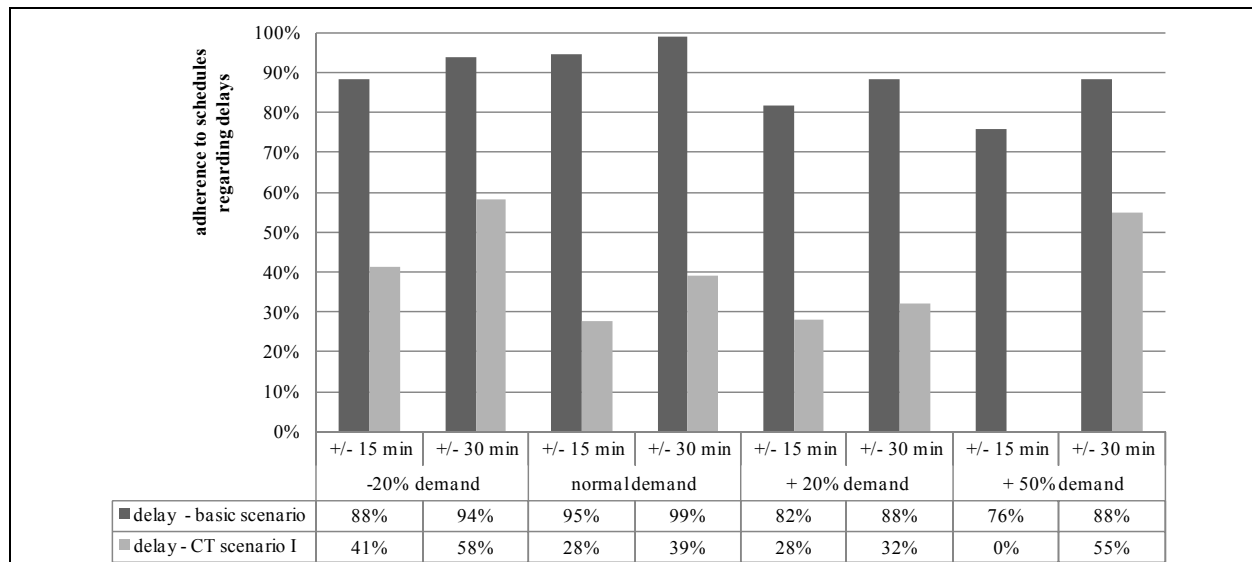


Figure 5 - 32: Adherence to schedules regarding delays - comparison between basic and CT scenario I.

Transition In brief, the analysis of CT scenario I shows that the integration of CT negatively influenced adherence to schedules and positively influenced the emissions of the analysed SC concept. The lower level of adherence to schedules mainly resulted from the enhanced lead times. Furthermore, the analysis of the lead times shows that there was still a significant share of waiting times. These waiting times could be interpreted as the initial points to open up the temporal quota to support CT integration.

The discussions with the experts proved that an increase in the order lead time and the resulting inventory increase would be reasonable.¹⁷⁵ However, the significant reduction of reliability was not acceptable to the experts. Thus, based on the considerations in chapter 3 and 4, in the following sections specific adaptations to production (cf. section 3.3.3.3) and distribution concepts (cf. section 3.3.2.3) are introduced that initially aim to improve the SCP in terms of adherence to schedules.

5.7.3 CT Scenario II – Production Concept Adaptation

CT scenario II was based on CT scenario I. It differed from CT scenario I in terms of production concept configuration. Section 3.3.3.3 identified the production control logic, type of order release, secondary order release and the stocking type as adaptation points for the production concept configuration to improve CT integration. In the simulation model, the generation of products in the DC was used to model changes to the production concept. Namely, the product generation times were adapted to model the effect of changes in the *production control logic* and *order release*. Based on the analysis of the delivery windows and the train schedules, new order picking (product generation times), loading and DC departure times were determined.

The specific adaptations to the production concept are explained by means of an example. Based on the SCP analysis of CT scenario I, the improvement of adherence to schedules was of paramount interest. Furthermore, it was assumed that the improved alignment of material flows would reduce waiting times at the terminals, thus resulting in lead time and inventory reductions.

Figure 5 - 33 visualises the desired effect. The figure's upper half shows the as-is situation with unimodal road transport for transport route M 3 (basic scenario). On transport route M 3, the vehicles load goods at the DC Möhlin in the morning and deliver them in the afternoon to the Morges and Chavannes stores and in the following morning to the Nyon store.¹⁷⁶ The SCP analysis of CT scenario I shows that without adaptations to the production concept, deliveries were late by an average of 0.98 hours in Morges and by 0.46 hours in Chavannes. Since the store in Nyon receives the delivery the following morning, there was no delay.

¹⁷⁵ Here especially the product value must be considered. For instance, for different products with higher mean values, e.g. electronics or automotive parts, an increase of order lead time and the resulting capital commitment could prevent CT integration.

¹⁷⁶ The driver stays overnight with the truck near the last store on the transport route.

To meet the designated delivery windows, on transport route M 3 goods must be transported by the train leaving the Härkingen terminal at 11:38 AM. Goods can be transported to the stores 30 minutes after the train's arrival at the Daillens terminal. Thus, catching the train at 11:38 AM ensures meeting the delivery windows in Morges and Chavannes.

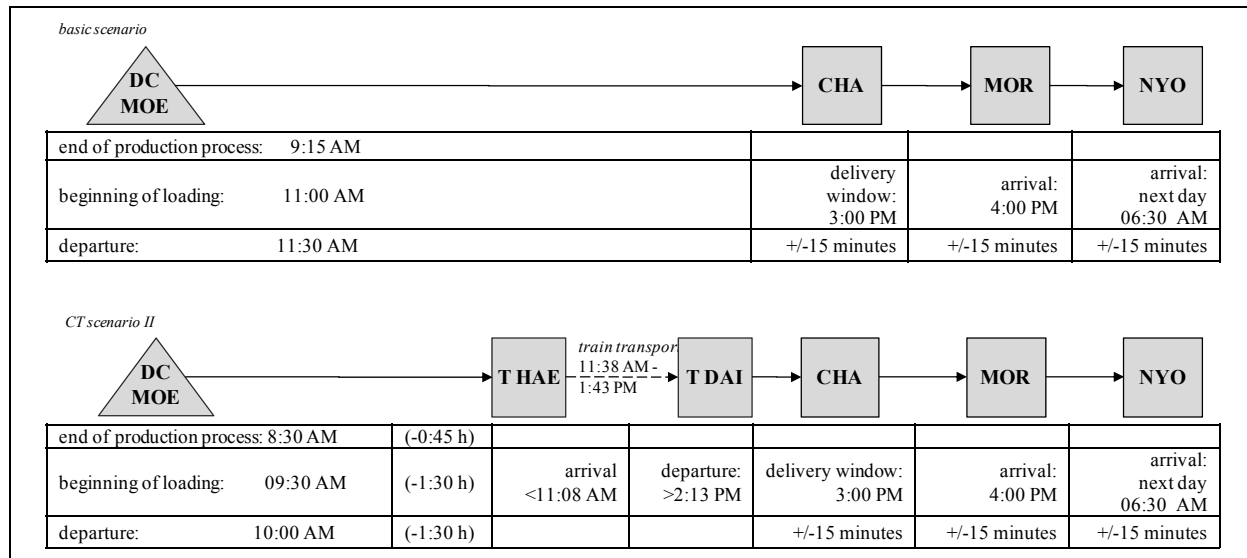


Figure 5 - 33: Effect of production concept adaptation on train schedule and delivery windows.

Following the presented example, new product generation and loading times were defined for all transport routes. The transport routes that contain only stores with next day deliveries (H 220 and M 24) showed no delays in the SCP analysis of CT scenario I. Hence, no adaptations were necessary in this case. Table 5 - 17 summarises all adaptations to the production concept.

route	product generation (end of order picking)	loading	departure DC	store 1	store 2	store 3
M 1		-0:30 h	-0:30 h	GEN	VES	
M 2		-1:15 h	-1:15 h	MON	LAU	VEV
M 3	-0:45 h	-1:30 h	-1:30 h	CHA	MOR	NYO
M 24	no adaptations necessary					
H 60	-2:00 h	-2:00 h	-2:00 h		CHA	
H 63	-1:20 h	-1:20 h	-1:20 h	VEV	LAU	
H 70	-1:00 h	-1:30 h	-1:30 h	GEN	VES	
H 75	-3:00 h	-3:00 h	-3:00 h	MON		
H 240	no adaptations necessary					

Table 5 - 17: Adaptations to the production concept.

It is assumed that the adaptations of the production concept led to an improvement in the adherence to schedules. However, for an encompassing evaluation of the adaptations' effect on SCP, the impact on the other performance indicators must be examined. Thus, in the following section the impact on order lead times and inventories are evaluated. Utilisa-

tion of road transport vehicles and emissions were not analysed for this scenario because the values did not differ from CT scenario I. There was no impact on the utilisation and emission performance indicators either, since the demand quantities, available transport resources and routes were not altered. However, in reality, the adaptations made may have caused changes that could not be modelled in the simulation model. A qualitative evaluation of the possible effects can be found in the concluding discussion (cf. section 5.7.5)

Utilisation of Trains – CT Scenario II

Figure 5 - 34 shows the capacity utilisation of the three trains used for the transport of goods in CT scenario II. This illustration shows that even for the reduced demand situation of -20%, the capacity of train T1 at 11:38 AM was at the maximum. This caused additional waiting times and thus an enhancement in lead times and a decline in adherence to schedules. For the normal and increased demand situations, the effect on waiting times at the terminal was even stronger.

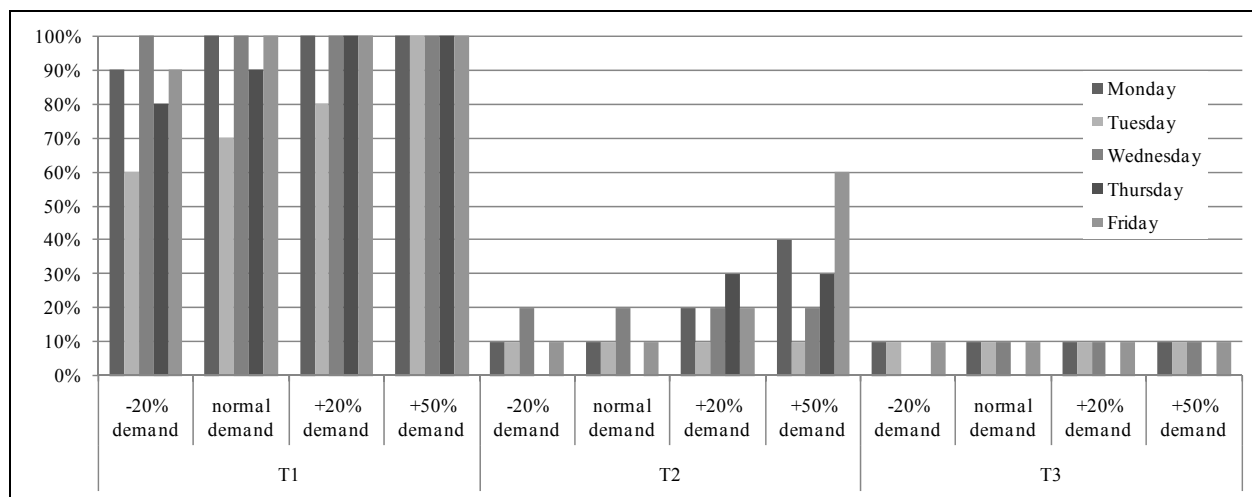


Figure 5 - 34: Utilisation of trains for CT scenario II.

Order Lead Time – CT Scenario II

The effect of the adaptations to the end of order picking, loading and departure to train schedule and delivery windows was reflected in the order lead times. Figure 5 - 35 contrasts the order lead time elements of CT scenario II and CT scenario I. The illustration shows that the average lead time was reduced by 9% because of the adaptations to the production concept for the normal demand situation. The improvement can mainly be affiliated with the reduction in waiting times of 32%. Also, transport time was slightly reduced. The reason for the transport time reduction was the balancing of arrivals at the stores. This means that trucks did not have to wait for unloading because the vendor dock was occupied.

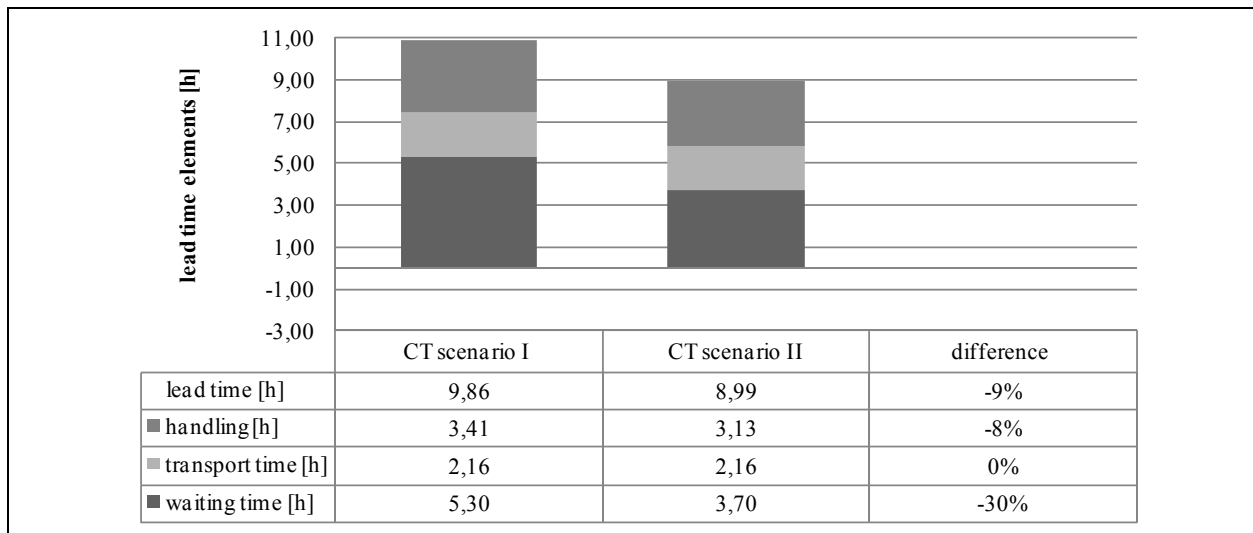


Figure 5 - 35: Transport time elements per store for CT scenario II for the normal demand situation.

The adaptations to the production concept were defined according to the conditions of the normal demand situation. Hence, lead time improvement was the biggest in this case. Figure 5 - 36 contrasts lead times for the different demand situations. In the basic scenario and CT scenario I, lead time was connected disproportionately with the increase in demand. The reason was that the demand increase primarily influenced the handling times, which is only one element of lead times. Furthermore, lead time enhancements caused by waiting times in the terminals because of missed train capacities reinforced the effect.

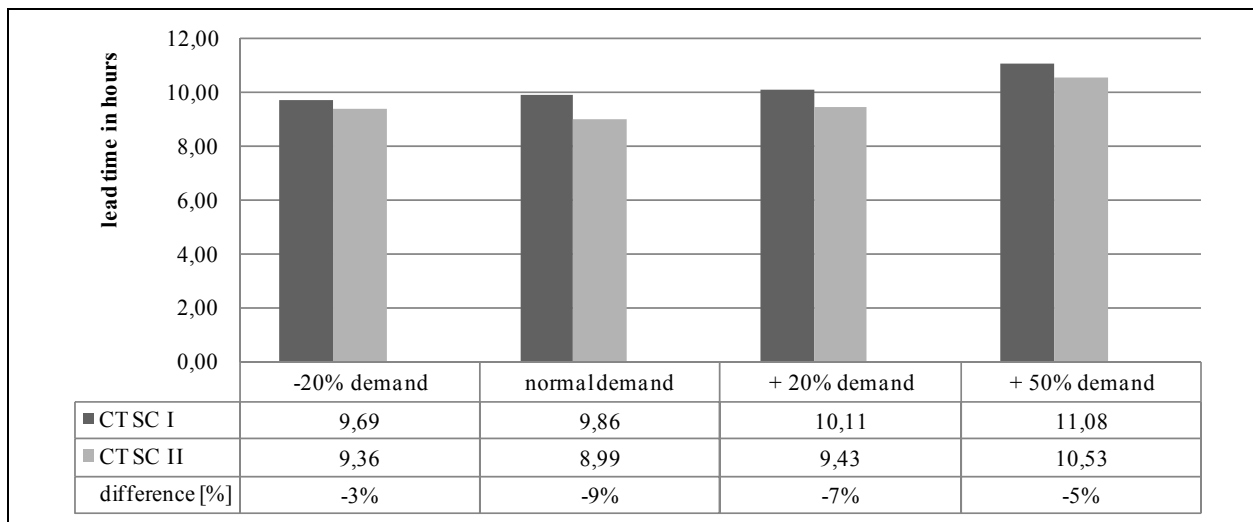


Figure 5 - 36: Comparison of lead time for different demand situations between CT scenario I and CT scenario II.

Inventory Level – CT Scenario II

In comparison with CT scenario I, the inventory in CT scenario II was reduced. The main reason was the shortening of order lead times.

Figure 5 - 37 visualises the average inventory level per store and DC. For most stores, a slight reduction in inventory levels was achieved by the adaption of the production concept.

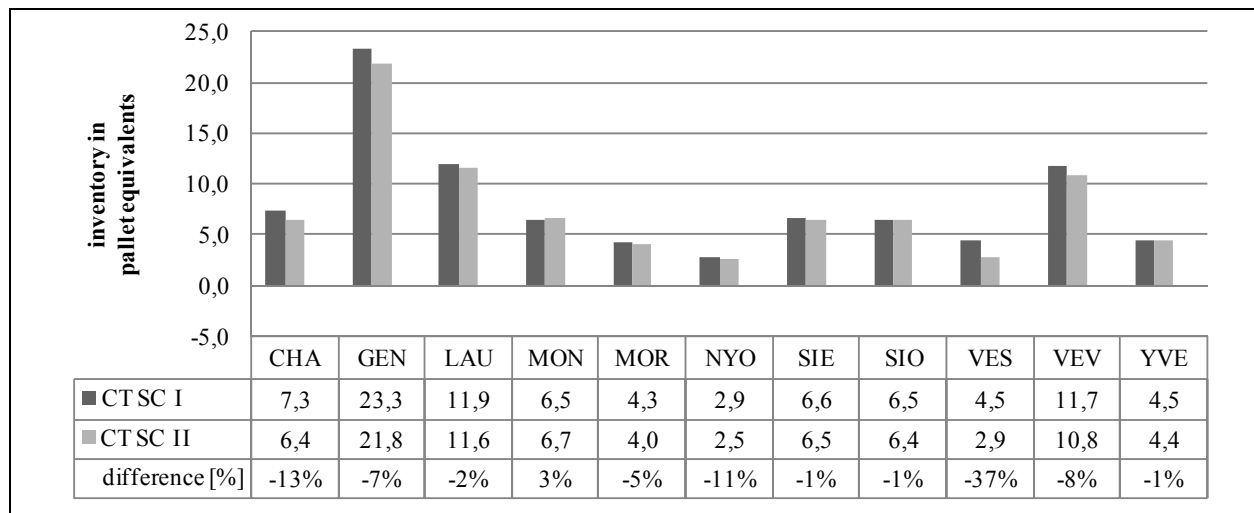


Figure 5 - 37: Average inventory in the transport between DC and stores for CT scenario II in comparison with CT scenario I.

Figure 5 - 38 contrasts lead times for different demand situations for CT scenario II. As for the basic scenario and CT scenario I, inventory appears to be connected in a more than proportionate way with the demand. An increase in demand of 20% caused an increase in inventory of 34%. However, for the increase in demand of 50%, only a 46% rise in inventory can be observed. This system behaviour can be attributed to the higher number of additional road transport and the resulting decrease in average lead times. Thus, in comparison with CT scenario I, in this analysis the effect of the reduced waiting times with full capacities was even stronger; thus the inventory level rise was not that significant.

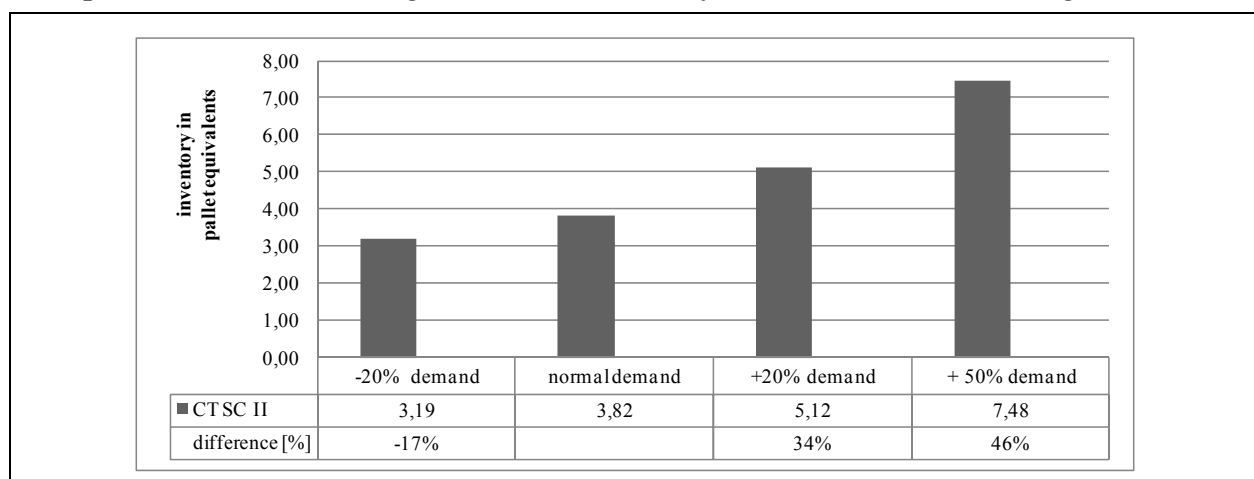


Figure 5 - 38: Comparison of lead time elements for CT scenario II for different demand situations.

Adherence to Schedules – CT Scenario II

The main focus of the production concept adaptation was the improvement of the adherence to schedules, which was strongly negatively affected by CT integration in CT scenario I.

Figure 5 - 39 illustrates the reduction in delays for the different stores in comparison with CT scenario I. To improve the clarity of the diagram, the analysis in CT scenario II initially focuses on adherence to schedules regarding delayed deliveries.¹⁷⁷ As for CT scenario I, the stores with next day delivery are not included in the diagram. In total, the adaptation of product generation times reduced the mean delay of transport from 2.07 hours to 0.68 hours. The effect strongly varied for the different stores. The reason for this strong variance can be found in the number of stores per route and the average demand. For the transport routes with three delivery points, the utilisation of vehicles and the number of pallet equivalents was comparably high; thus handling times varied more intensively. Consequently, the risk of missed trains and delayed arrivals was increased. The illustration shows that this argument is especially valid for the big stores with high demands, for instance in Vevey and Geneva, and for the stores that are last on the transport routes, such as Morges, Vésenaz and Vevey.

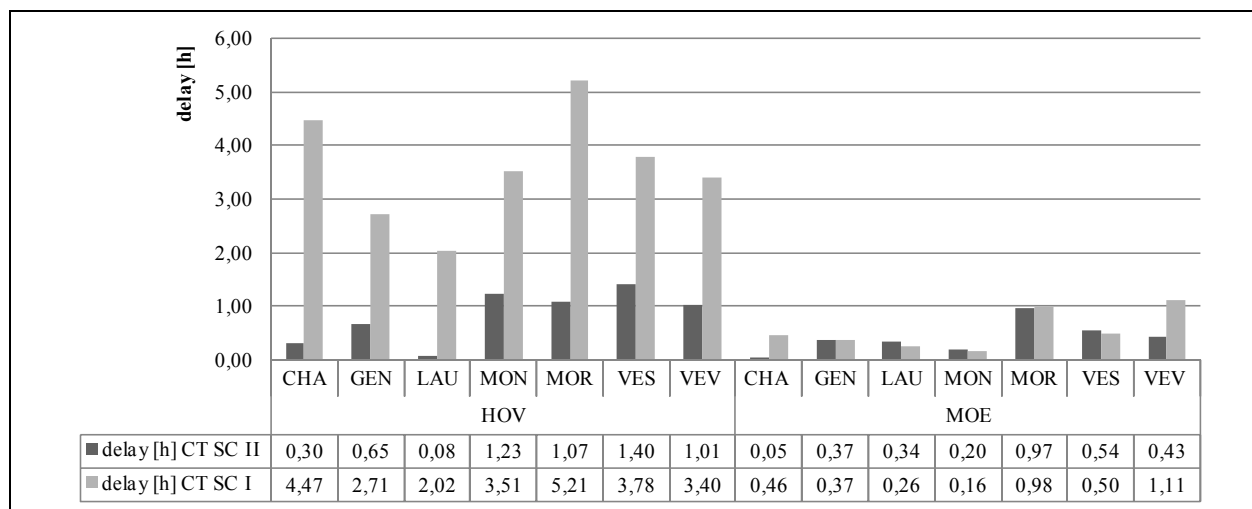


Figure 5 - 39: Comparison of delay between CT scenario I and CT scenario II.

Figure 5 - 40 shows that the adherence to schedule in CT scenario II was significantly improved over that in CT scenario I. For the normal demand situation, an improvement

¹⁷⁷ This focus corresponds to reality: in cases where they reach the site too early, truck drivers wait nearby the destination store until the delivery window.

from 28% to 39% (+/- 15 minute delivery window) and from 39% to 54% (+/-20 minute delivery window) was achieved. It is evident that for higher demand situations, the effect on the adherence to schedules is nearly constant for all demand situations.

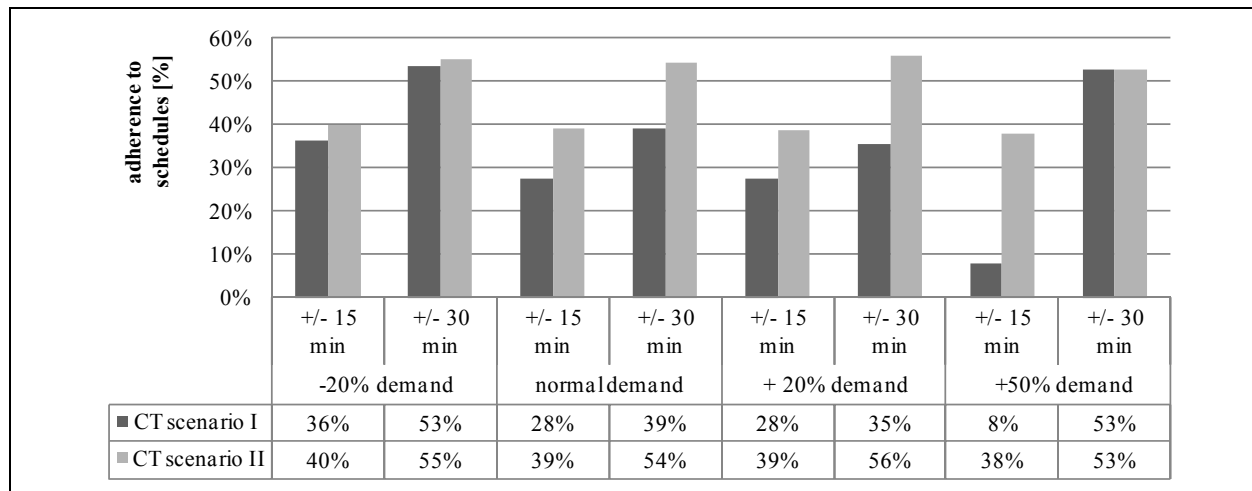


Figure 5 - 40: Comparison of adherence to schedules for different demand situations.

Table 5 - 18 summarises the key figures for different demand situations.

	-20% demand		normal demand		+20% demand		+50% demand	
	+/-15 min	+/- 30 min	+/-15 min	+/- 30 min	+/-15 min	+/- 30 min	+/-15 min	+/- 30 min
adherence to schedules regarding deviations (too early and too late deliveries)	40%	55%	39%	54%	39%	56%	38%	53%
adherence to schedules regarding delays (too late deliveries)	41%	56%	41%	55%	41%	57%	40%	54%
mean deviation [h]	0.73		0.73		0.80		0.81	
mean delay [h]	0.73		0.73		0.78		0.79	

Table 5 - 18: Overview of key figures regarding the adherence to schedules for CT scenario II.

The reason that CT scenario II did not reach the same adherence to schedules rate as the basic scenario was due to the risk of missing the defined train departure times. In a uni-modal road concept, a few minutes delay to a particular transport vehicle (e.g., caused by longer loading times due to additional transport quantities) causes a few minutes delay to the delivery. In a SC concept including CT, the effect of a few minutes delay at the loading can cause several hours delay for the delivery if the truck misses the designated train. Furthermore, the analysis of train utilisation has shown that in CT scenario II, the train capacities were not sufficient. Thus, shipments were delayed and the adherence to schedules decreases.

Since the adaptations to the production concept were based on normal and average demand quantities, the adaptations need to be small to reach an acceptable level of adherence to schedules; larger temporal shifts may require further operational adaptations. Nev-

ertheless, the analysis generally proves that adaptations to the production concept with regards to a specific CT concept can be utilised to improve SCP.

The following section analyses the SCP effect of adaptations to the distribution concept with regards to a specific CT concept.

5.7.4 CT Scenario III – Distribution Concept Adaptation

CT Scenario III was also based on CT scenario I. It differed from CT scenario I in terms of the distribution concept configuration. Section 3.3.4.3 identifies the regional structure, echelon structure, delivery service and the delivery time point as adaptation points to positively influence the performance-oriented CT integration.

In accordance with the views of the experts from *Manor*, an adaptation of the regional structure or echelon structure was not possible. Thus, the simulation study was used to model adaptations to the *delivery service* and *delivery time point*.

The discussions with the experts showed that alterations to the delivery windows in the stores require operational changes in the store processes. Personnel-intensive storage processes would have to be temporally shifted. In several stores, products are ordered in the morning and delivered in the afternoon. However, in many stores, the storage of products on the shelves does not take place until the next morning. These considerations indicated the need to accomplish a two-step analysis.

First, the SCP impact of shifting delivery windows from the initial time point in the afternoon to a later time point was examined. The temporal shift was accomplished according to the given product generation, loading, departure times and train schedule (CT scenario III). Second, the SCP impact of shifting delivery times from same day to next day delivery was examined (CT scenario IIIa).

Figure 5 - 41 concretises the changes in the simulation scenario. The figure's upper half shows the as-is situation with unimodal road transport for transport route H 75. Assuming that the product generation, loading and departure times were not alterable, the truck arrives at Härkingen terminal at approximately 12:30 AM. The shipment is conveyed by the train leaving the terminal at 2:41 PM.¹⁷⁸ After arrival at 4:31 PM and transshipment (30 minutes), the truck leaves the terminal at 5:01 PM. The transport from Daillens terminal

¹⁷⁸

It is also possible that the transport meets the train at 11:38 AM, but there is only a small temporal buffer of 8 minutes that can be affected by the duration of loading, as well as fluctuation in transport and loading times.

to the Morges store (44 km) takes approximately 53 minutes. Thus, a shift in the delivery window by 1 h to 6:00 PM was suggested.

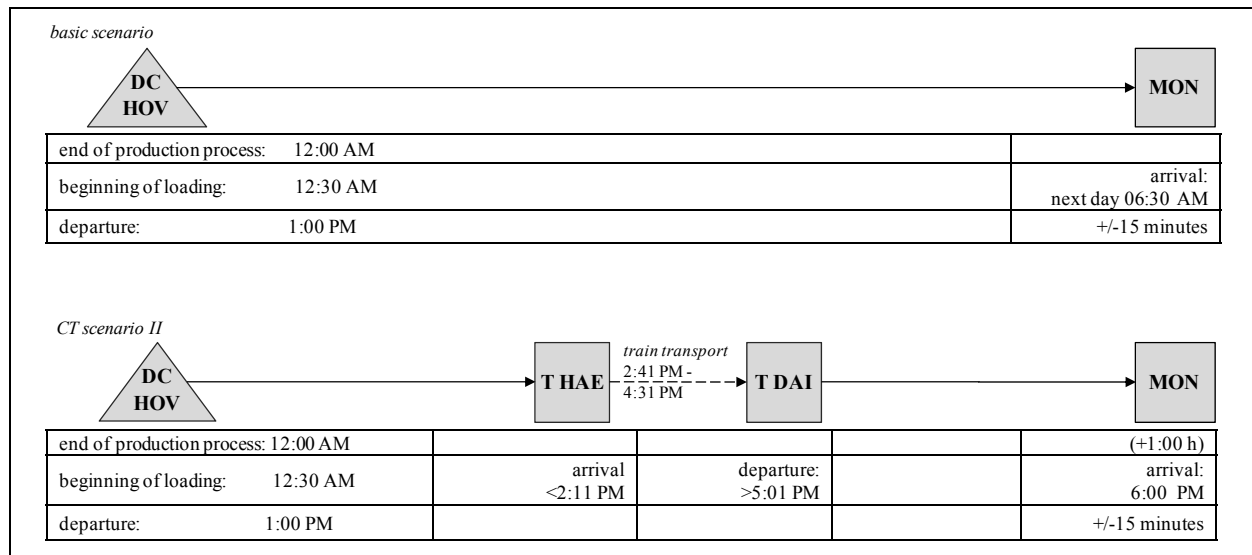


Figure 5 - 41: Effect of distribution concept adaptation to train schedule for transport route H 75 (CT scenario III).

In accordance with the example presented, Table 5 - 19 summarises all the adaptations to the distribution concept for CT scenario III.

route	product generation	loading	departure DC	arrival store 1	arrival store 2	arrival store 3
M 1	7:45 AM	10:00 AM	10:30 AM	GEN +2:30 h	VES + 2:30 h	
M 2	8:15 AM	10:45 AM	11:15 AM	MON +1:30 h	VEV +1:30 h	LAU +1:30 h
M 3	9:15 AM	11:00 AM	11:30 AM	CHA +2:00 h	MOR +2:00 h	NYO +2:00 h
M 24	11:45 AM	2:15 PM	2:45 PM	no adaptations necessary		
H 60	11:00 AM	11:30 AM	12:00 AM	MOR +1:45 h	CHA +1:45 h	NYO +1:45 h
H 63	10:20 AM	11:00 AM	11:30 AM	VEV +2:00 h	LAU +2:00 h	
H 70	10:00 AM	11:00 AM	11:30 AM	GEN +1:00 h	VES +1:00 h	
H 75	12:00 AM	1:00 PM	1:30 PM	MON +1:00 h		
H 240	3:10 PM	4:00 PM	4:30 PM	no adaptations necessary		

Table 5 - 19: Adaptations to the distribution concept for CT scenario III.

In the following section, the effect of the adaptations to the distribution concept on SCP is analysed.

Order Lead Time – CT Scenario III – Distribution Concept Adaptation

In comparison with CT scenario I, the adaptation of the distribution concept was reflected by enhanced order lead times in CT scenario III. Figure 5 - 42 illustrates the lead times for CT scenario III in comparison to the results of CT scenario I for different demand levels. The illustration shows that for CT scenario III, the effect of lead time enhancement was less significant for higher demand levels (only 6% and 9% for the 20% and 50% increased demand situation in contrast with 12% each for the normal and reduced demand situation).

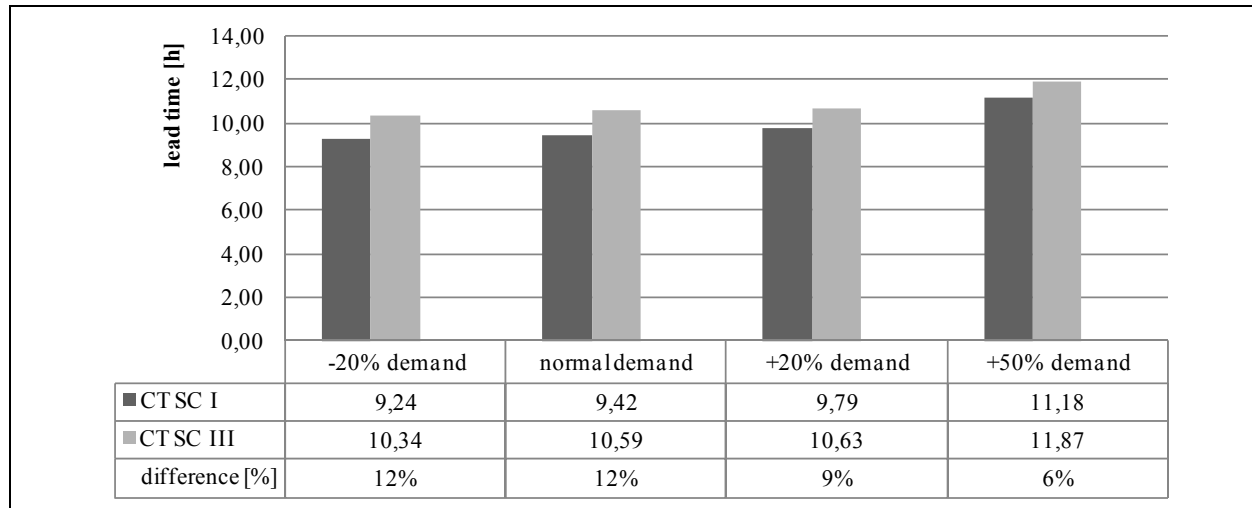


Figure 5 - 42: Comparison of lead times of CT scenario I and CT scenario III for different demand situations.

The enhancement of lead times was caused by the shift of delivery windows to a later time point. As a result, the products were removed from the simulation at a later time point. As shown previously, the demand situation influences the lead time in a disproportionate way. For CT scenario III, the reduced demand situation caused a reduction in lead times of 2%. In the case of 20% and 50% increased demand situations, the increases in lead times were 0.3% and 12%. The reason for the disproportionate connection was that only the handling times were directly affected by the changes in demand.

Figure 5 - 43 visualises the changes in lead time elements for the normal demand situation. The illustration shows that the adaptation of the distribution concept mainly increased the waiting time (+27%). The increase in waiting time resulted from the shift of delivery windows to a later time point. All deliveries arriving prior to these shifted delivery windows thus experienced additional waiting times. In total, the adaptations to the distribution concept raised the order lead time by 7%.

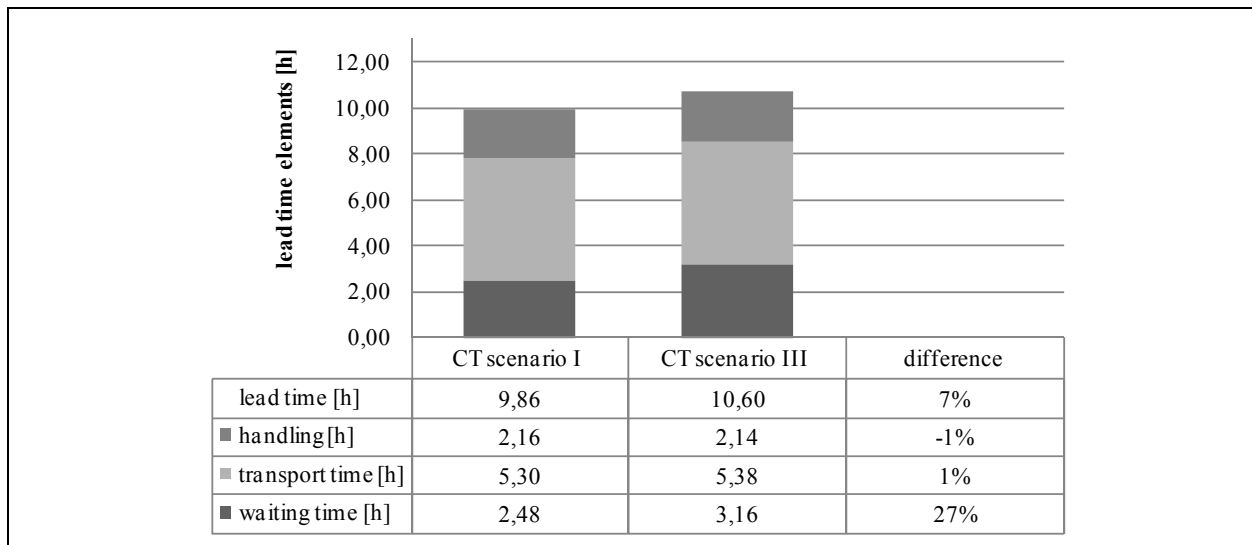


Figure 5 - 43: Comparison of lead time elements between CT scenario I and CT scenario III.

Inventory Level – CT Scenario III – Distribution Concept Adaptation

In comparison with CT scenario I, the shift of delivery windows enhanced the total lead times and thus the inventory levels. Figure 5 - 44 contrasts inventory levels for all stores and DCs for CT scenario III and CT scenario I. The illustration shows that the influence on the different stores was between 0% and 16%. There were no changes for the Nyon, Sierre, Sion and Yverdon stores because these have next day delivery and no adaptations were made. In total, the increase in inventory levels was proportionate to the increase in lead time of 7%.

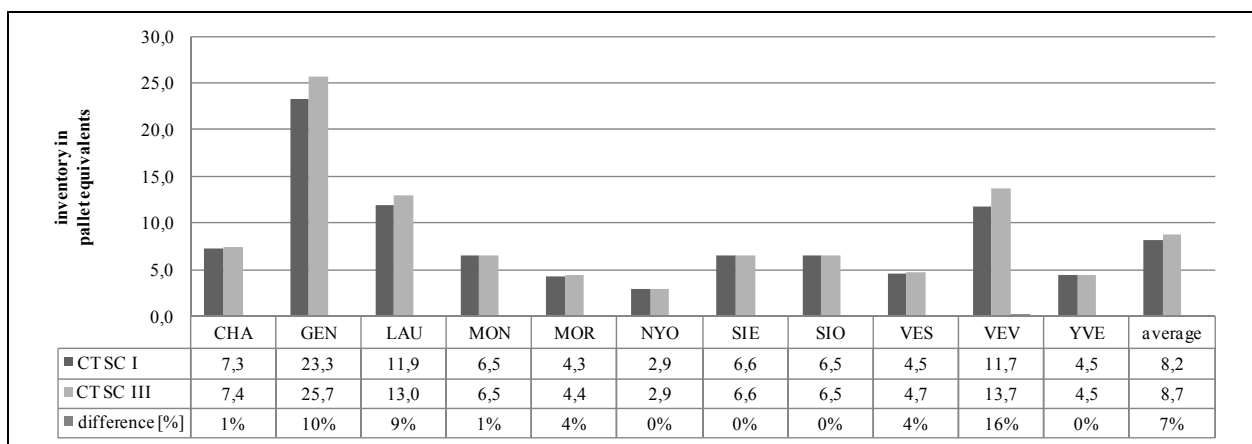


Figure 5 - 44: Average inventory in the transport between DC and stores coming from DC Hochdorf for CT scenario III.

Figure 5 - 45 compares the inventory levels for the different demand situations. As explained for the previous scenarios, the reason for this disproportionate increase in inventories was the combination of effects regarding increased lead times and higher transport quantities because of the higher demand.

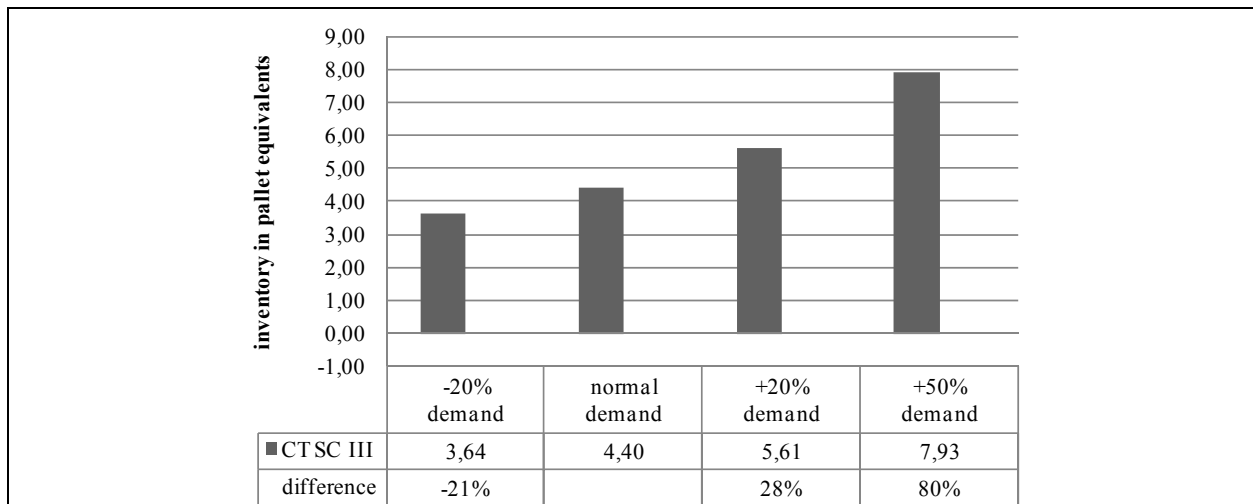


Figure 5 - 45: Inventory levels for different demand situations - CT scenario III.

Adherence to Schedules – CT Scenario III - Adaptations to the Distribution Concept

Figure 5 - 46 visualises the improvement in the adherence to schedules regarding the too late deliveries by the adaptation of the distribution concept.

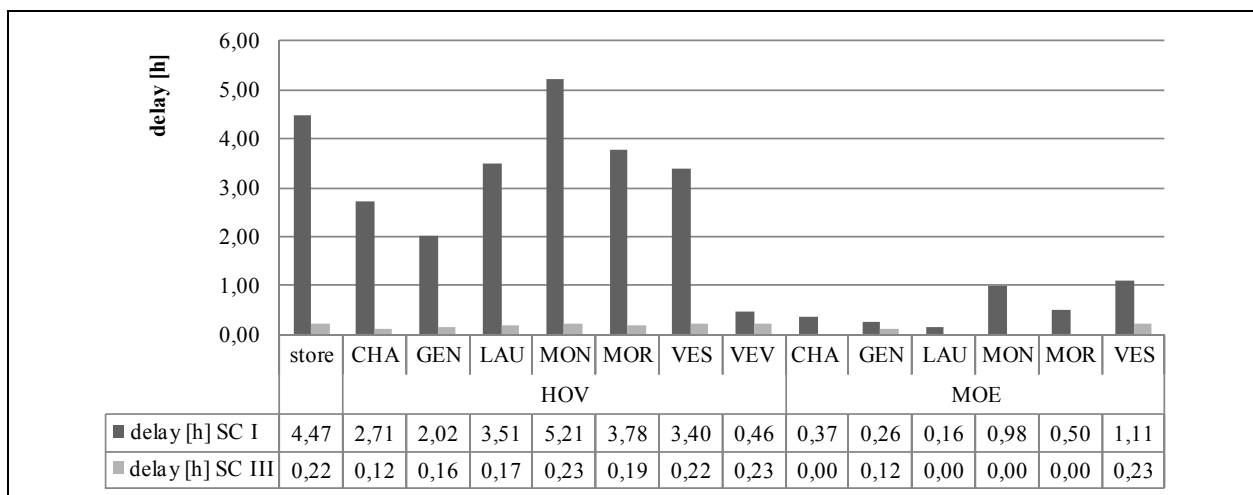


Figure 5 - 46: Comparison of delay between CT scenario I and CT scenario III.

Figure 5 - 47 visualises the improvement in adherence to schedules regarding too late deliveries. For the normal demand situation, the adherence was increased to 84% for a delivery window of +/- 15 minutes and to 92% for a delivery window of +/- 30 minutes. For the reduced demand situation, the adherence to schedules was even better: 85% and 96%. For the 20% increased demand situation, the adherence to schedules reached 80% and 92%. Only for the 50% increased demand situation did the adherence to schedules decrease, to 64% and 75%.

The illustration shows that the effect of the distribution concept adaptation regarding the CT concept was best for the normal and the reduced demand situation, since the adapta-

tions were defined according to the normal demand situation. Thus, it can be assumed that when shifting the delivery windows to a later time point, the adherence to schedules would be increased for higher demand levels.

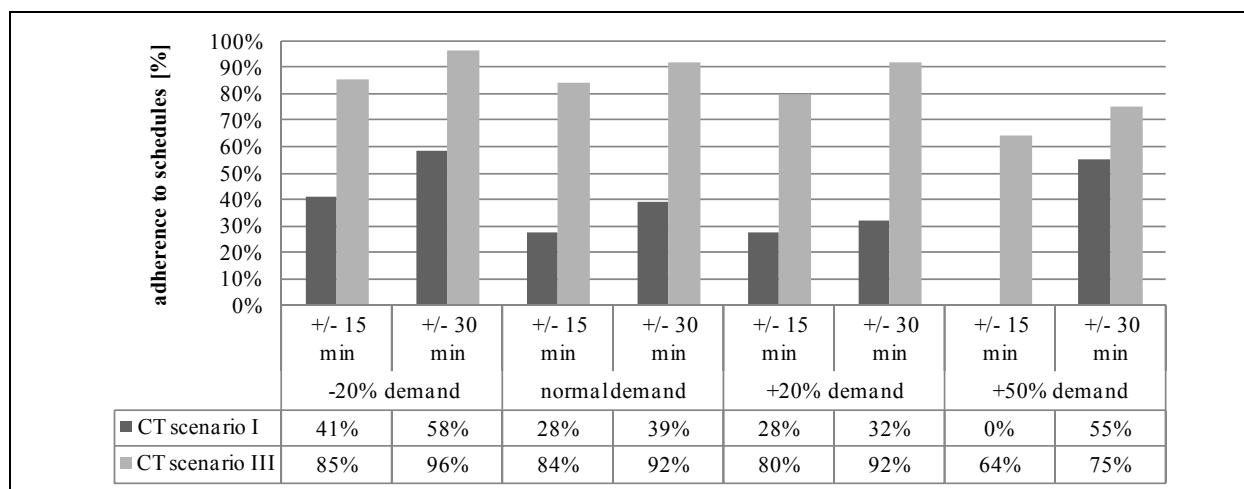


Figure 5 - 47: Comparison of adherence to schedules regarding delays for different demand situations.

Delivery Service Shift to Next day Delivery

Finally, the shift in delivery time from same day to next day delivery was analysed. The simulation results and the discussion with the experts showed that this adaptation of the distribution concept would mean a number of significant advantages for implementation in practice.

The first reason is that shifting delivery windows to the evening hours (as accomplished in CT scenario III) would require relevant operational changes, as stores may already be closed. If the goods can be deloaded and buffered in the evening, there will be no personnel for storing goods on the shelves. Even if moving the shifts of the replenishment personnel were possible, there would be no customers to profit from the availability of goods.

The second reason is that goods could be transported on rail at night time. During the night time driving ban, the terminal operator could autonomously decide on which train to put the shipments. The enhanced time span would improve the terminal operator's capacity planning. This is an important aspect, particularly when the capacity of the CT trains is used to the full (as shown for CT scenario II and III). Thus, by incrementing the waiting times at the terminals, the resulting enhancement of lead times and delivery delays could be avoided. Also, the charged road carriers would have additional freedom in terms of loading and delivery times, since there are no specific delivery windows at the *Swiss Post*

terminals.¹⁷⁹

However, no separated analyses of the adherence to schedules were accomplished for shifting the delivery times to the next morning. It is assumed that the adherence to schedules in the next morning could reach at least the level of the basic scenario, since from Dailiens terminal there are only comparably short road distances to travel to serve the stores. The risk of congestion and delays is thus comparably small.

There were no changes in the utilisation of transport vehicles and the emission levels that could be modelled by means of the simulation study. A qualitative evaluation is accomplished in the concluding discussion (cf. section 5.7.5).

Lead Time - CT Scenario IIIa - Shift to Next Day Delivery

In the simulation, the shift of delivery times significantly increased the waiting times. The additional waiting time overnight caused an increase in the overall waiting time of 277% and in total lead time of 90%. The additional time span was sufficient to deliver all goods, even for the increased demand situations. Thus, lead time was identical for all demand situations. Figure 5 - 48 visualizes the considerations.

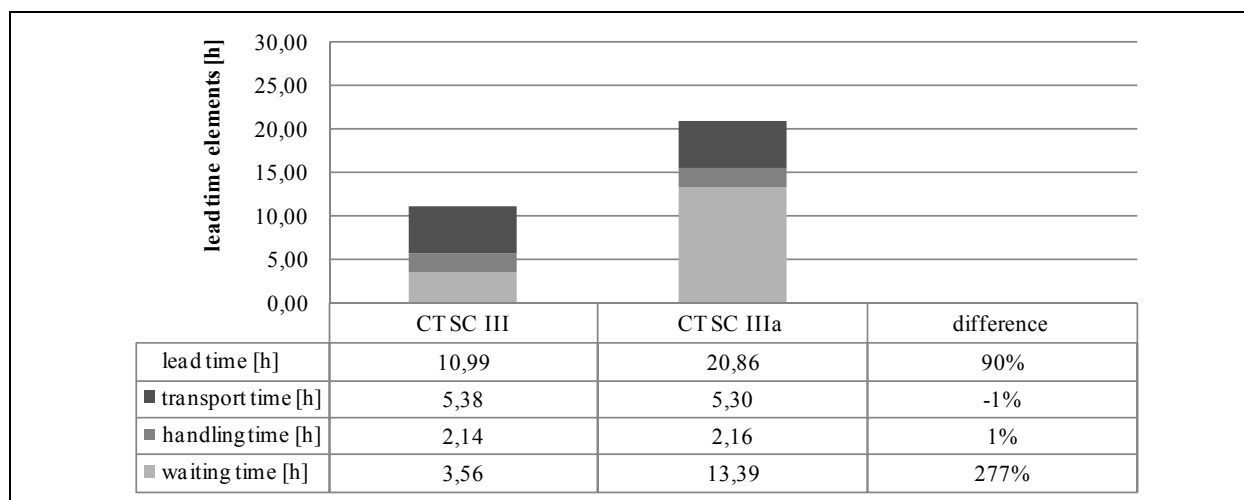


Figure 5 - 48: Comparison of lead time elements for CT scenario III and CT scenario IIIa.

Inventory - CT Scenario IIIa

The adaptation of the delivery times to a next day delivery for all stores also caused an increase in inventories. Figure 5 - 49 shows that the shift of delivery windows approxi-

¹⁷⁹ From the shipper's point of view, it could be assumed that the terminal operator and even the road carrier offer improved prices if they are not restricted to use one certain train for the shipment's transport.

mately caused a doubling of inventories. The effect was not linear to the lead time enhancement because the average inventory was calculated as the integral of the inventory course over the time.

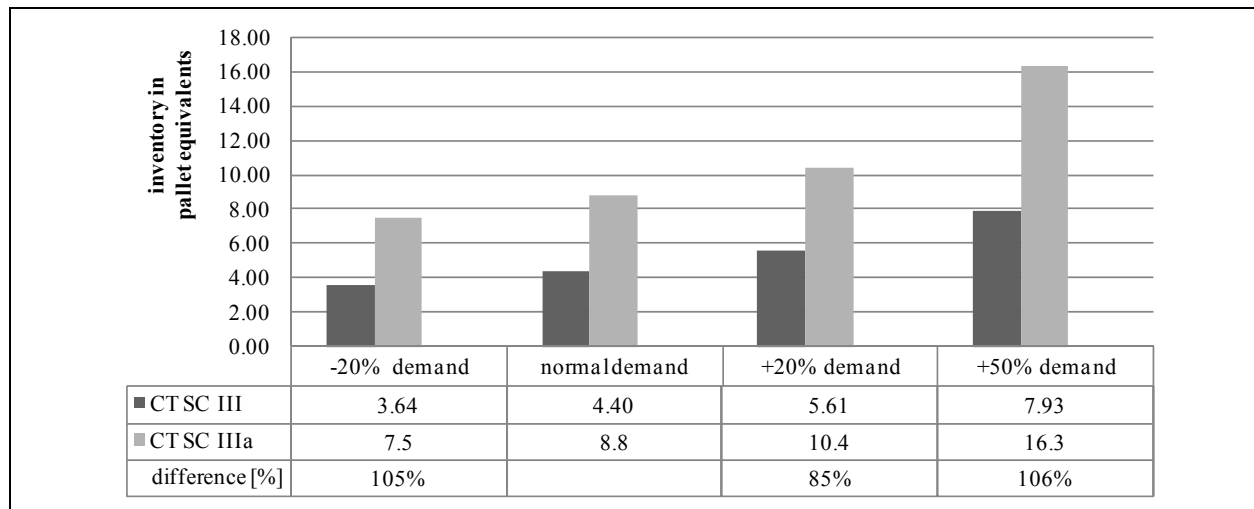


Figure 5 - 49: Comparison of inventory levels for CT scenario III and IIIa for different demand situations

Finally, the results of all the simulation scenarios are compared and discussed. In particular, the findings are compared with the expected results (E_1 to E_6). In response to the findings in the thesis in hand, practical recommendations and limitations of the research are derived and explained.

5.7.5 Discussion of Simulation Results

The simulation study shows that SCP can be increased when the SC concept, namely the production and distribution concepts, are aligned with the embedded CT concept. Section 5.3.5 presents the discussion of the SCP effects and the six statements of expected results (E_1 - E_6). Furthermore, unexpected results, such as non-linear cause-and-effect relationships are discussed. Finally, the generalisability and transferability of the findings are evaluated.

SCP Effect of CT Integration into a Lean SC Concept

As a first step, the performance-effect of the CT integration in comparison to the SC concept based on unimodal road transport is evaluated in the following section. Therefore, SCP of the basic scenario is contrasted with the SCP of the analysed CT scenarios.

E₁: The integration of CT impacts SCP in terms of (a) enhancement of lead time, (b) adherence to schedules and (c) reduction of emissions (in comparison with a unimodal road transport concept).

a) The simulation study shows that CT integration causes a significant enhancement of lead times. The effect is less than proportionate for all scenarios and demand situations. CT integration without adaptations to the SC concept led to an increase in lead time of 24%. The increased lead times resulted from increased transport times (because of rail transport), handling times (because of additional transshipment processes) and waiting times for the next train departure at the terminal in the case that a train is missed.

Adaptations to the production concept, namely changes to the product generation time, reduced this increase in lead times by 13%. Adaptations to the distribution concept, namely shifting delivery windows by a few hours, caused an increase of 31% in terms of improved lead times; a shift to next morning delivery caused a rise of 162%.

Adaptations to the SC concept were made with the target to show cause-and-effect relationships between the elements of the CT, the SC concepts and the resulting SCP effect, rather than to optimise the modelled SC. Thus, it can be assumed that further improvements could be achieved for a more detailed analysis of the initial situation and the accomplishment of more specific adaptations (for instance, different adaptations for different weekdays). For instance, the analysis of CT scenario III shows that there were contradictions in the SCP system. A smaller shift in the delivery windows would have positively influenced total lead time, but negatively influenced adherence to schedules.

Thus, for the generalisation and transfer of results, company-specific SCP understanding and weighting of targets must be considered.

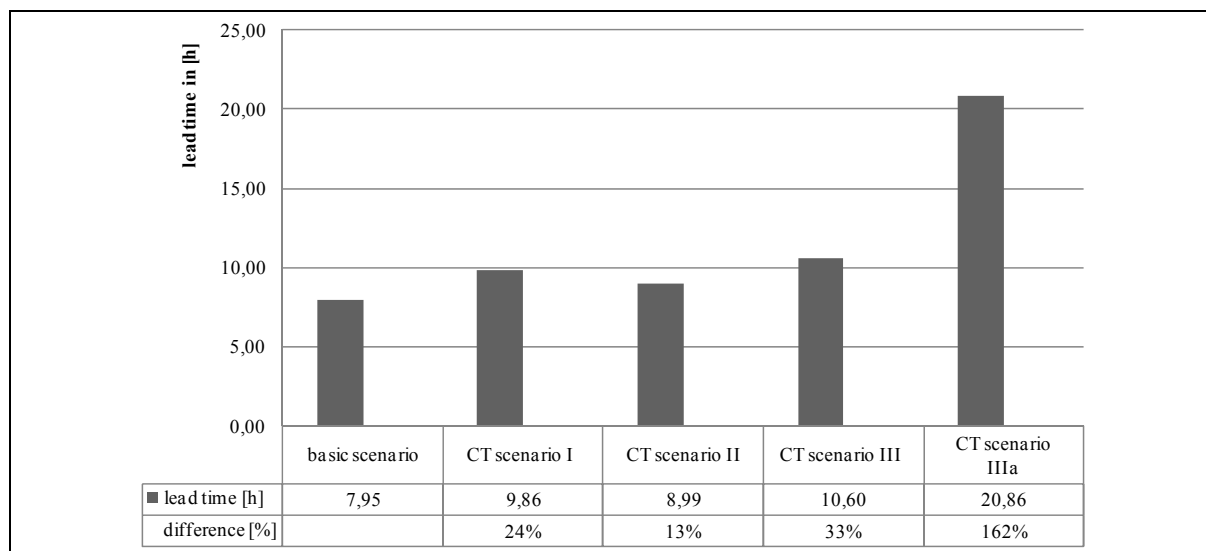


Figure 5 - 50: Comparison of lead time for different simulation scenarios.

b) The discussions with the experts proved the importance of adherence to schedules in the real system. The simulation shows that CT integration initially negatively affected

adherence to schedules. However, adaptations to the production and distribution concept with regards to the specific CT can effectively improve SCP in terms of adherence to schedules. Figure 5 - 51 contrasts the adherence to schedules for different demand situations regarding delayed deliveries. The figure shows that although improvements were achieved, only for CT IIIa was an acceptable level of adherence to schedules (more than 92%) for a +/-30 minute delivery window achieved. This indicates that an in-depth analysis of the SC concept and the CT concepts, as well as the specific framework conditions, is necessary to benefit from the findings presented in the thesis in hand. Furthermore, it can be assumed that a combination of aligned adaptations in different SC sub-concepts is even more effective than isolated adaptations.

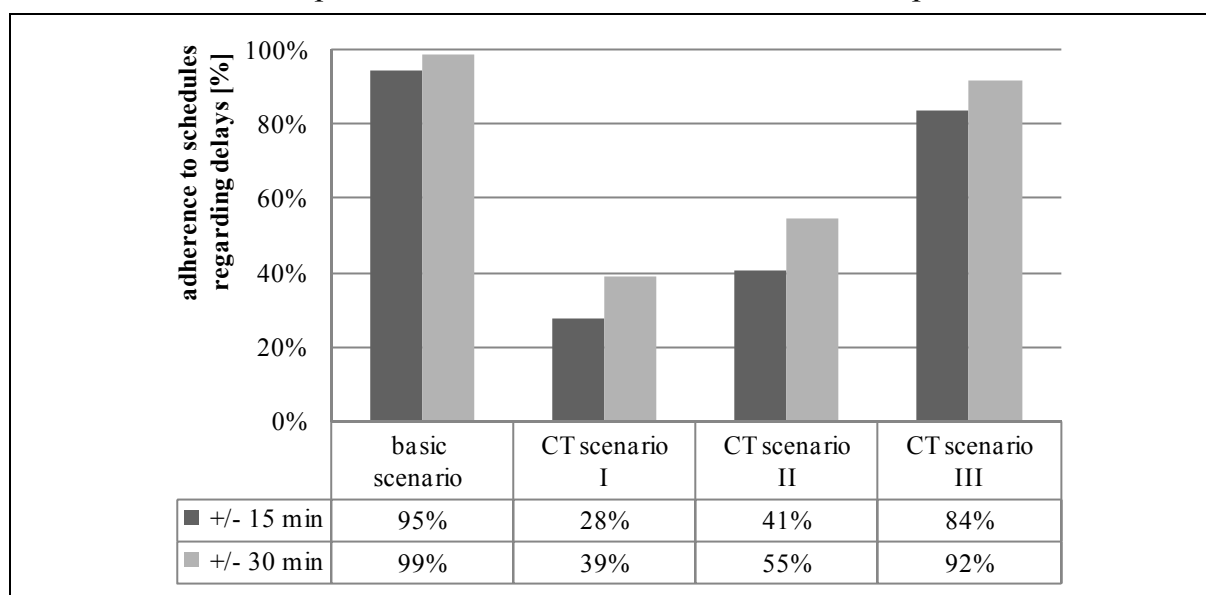


Figure 5 - 51: Comparison of adherence to schedules regarding delayed deliveries.

Adherence to schedules is interpreted in two different ways. In the chosen example of a lean retail SC, adherence to schedules regarding delays (namely the share of not-delayed deliveries) is central. However, in other industries, the share of deviations, (namely the share of too early *and* delayed deliveries) is significant. For instance, in highly frequent transport concepts with high-value goods (for instance in JIS-deliveries), a too early arrival must be as negatively evaluated as a delayed one. However, the analysis shows that the number of both delayed and deviated deliveries can be reduced by adaptations to the production and distribution concepts.

c) The analysis shows that CT integration significantly influenced SCP in terms of emissions levels. Table 5 - 20 projects the results from the one-week simulation run to calculate the possible savings in one year. However, discussions with the experts proved that the projection of results for a period of one year is necessary to compare

activities with other companies, but also for purposes within the corporate company, e.g., for emissions reduction activities. In total, *Manor* could save more than 300 tons of CO₂ per year through CT integration into the SC concept for the eleven stores in Western Switzerland alone.

total per year	basic scenario	CT scenarios	savings per year	unit
fuel consumption [l]	245.9	156.8	-88.97	in 1000 L
CO ₂ [t]	694.5	379.3	-315.19	in t
NO _x	7.3	4.3	-2.99	in t
particle [g]	0.2	0.1	-0.07	in t
distance road [km]	793.7	391.8	401.86	in 1000 km

Table 5 - 20: Comparison of projected emission factors and possible savings for one year.

E₂: The integration of CT allows the (a) reduction of road transport vehicles and the (b) improved utilisation of road transport vehicles.

The impact on the number and utilisation of transport vehicles could not be entirely answered by means of the simulation study. A number of different aspects must be considered to evaluate the impact of CT integration on the number of road transport vehicles. After CT integration for each transport route, two trucks are necessary: one truck for pre-haulage and one truck for ongoing-haulage.¹⁸⁰

For the calculation of utilisation levels, the loading on the first route segment after leaving the DC serves as the basis because here, utilisation reaches its maximum.¹⁸¹ On long transport distances, drivers stay with the goods overnight before store delivery the next morning. The simulation results indicate that in the case of CT integration, it is possible that each truck accomplishes two or more transport routes per day: either between a DC and a terminal or between a terminal and the stores. This balances the number of trucks to the level in the basic scenario. In particular, for trucks between terminal and stores, the share of idle driving distance can be reduced. Furthermore, no overnight stays of trucks and drivers are necessary. Depending on the specific framework conditions and concentrating single trucks to one region, this can mean that when a driver's shift is terminated, the truck can be further utilised. This increases utilisation in a wider sense. However, for quantification purposes, an in-depth analysis would be necessary.

In summary, the expected result of a reduced number of road transport vehicles could

¹⁸⁰ In the basic scenario one truck accomplishes the entire transport route.

¹⁸¹ With the first unloading process, utilisation decreases for each store delivery. Transport back to the DC was excluded from consideration.

not be confirmed but is presumable. The discussions with the experts indicated that a reduction is possible. The simulation results indicate that, especially for the transport vehicle accomplishing the store delivery, improved utilisation can be assumed.

E₃: CT integration leads to an (a) increase in the total inventory level and (b) a reduction of time flexibility (in comparison with a unimodal road transport concept)."

a) The simulation study shows that CT integration leads to an increased inventory level. Depending on order lead times and the log course over time, the inventory level was increased by 26% with CT integration, without adaptations to the SC concept in comparison with the basic scenario. The adaptations to the production concept reduced the inventory increase to 18%; adaptations to the distribution concept raised it to 35%. The shift of all delivery times to next day led to an increase in the total inventory level of 78%.

Figure 5 - 52 shows that the increase in inventory was less than proportionate to the lead time enhancement but more than proportionate to the changes in demand.

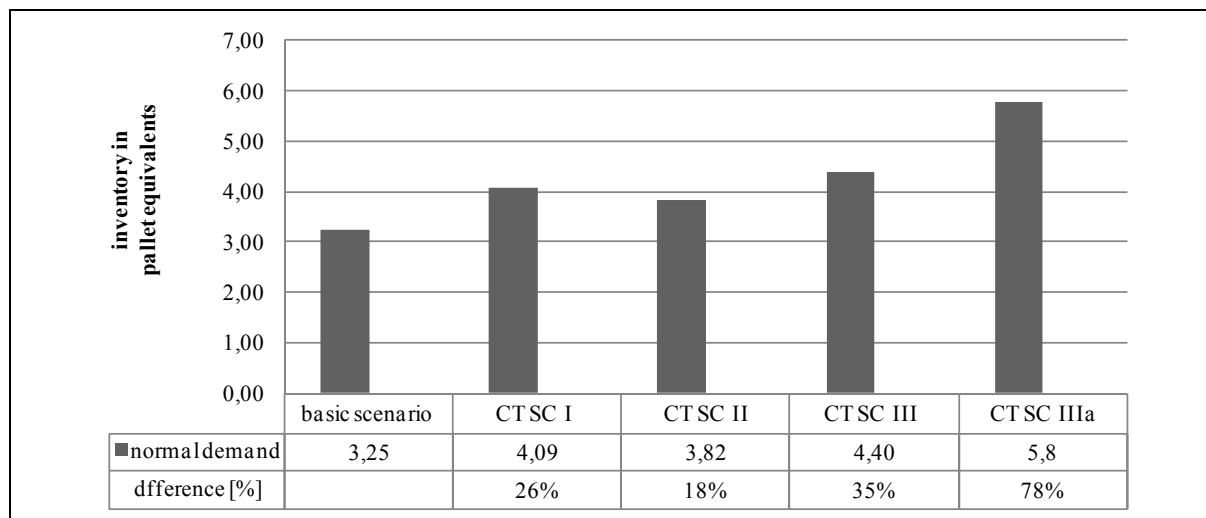


Figure 5 - 52: Comparison of inventory levels for all scenarios and for different demand situations.

b) Time flexibility could not be directly evaluated by means of the simulation study. However, the simulation results provide initial points for an argument regarding time flexibility. As shown in the discussion of the simulation results, catching specific trains is critical for SCP. For closely coupled material flow processes, missing designated trains does inevitably mean that the lead time is enhanced by at least the amount of waiting time.¹⁸²

¹⁸² This goes along with a raise of the average inventory level.

As shown in 3.1.4.1 lean SC concepts (type I - continuous replenishment) aim at the reduction of temporal buffers. Thus, delays at the terminal also mean that adherence to schedules is negatively affected.¹⁸³ Thus, CT integration causes a high deviation in lead times and adherence to schedules, which means restrictions are required for the predictability, 'plannability' and control of the SC concept. To avoid this effect, actors must focus their activities on meeting the designated trains. As a result, time flexibility is reduced, for instance expressed in short-term changes in departures or transport quantities. However, time flexibility can be ensured by an enhancement of delivery times (here modelled by the shift from same day to next day delivery), as shown for CT scenario IIIa. In this case, the terminal and CT operators gain flexibility and can balance capacities. In brief, a target conflict, between time flexibility and adherence to schedules, can be identified.

Performance Effect of Adaptations to the SC Concept

As a second step, the performance effect of single adaptations to the SC concept, namely adaptations to the production (E_4) and distribution concept (E_5), is discussed.

E₄: The harmonisation of production arrival times with the CT concept leads to a (a) reduction in lead times, (b) increased time flexibility and (c) improved adherence to schedules.

a) The analysis of CT scenario II shows that the adaptation of the product generation time reduced lead times on average by 9% in comparison with CT scenario I. The main part of the reduction was achieved by eliminating waiting times in the distribution concept. After the adaptation, the increase in lead times in comparison with the basic scenario was only 13%. The discussions with the experts showed that this increase in lead times and the resulting increase in inventory levels would be acceptable. Furthermore, the discussions proved that the suggested adaptations to the production concept are applicable in practice. Only the changes to the order picking process to allow an earlier departure for transport route H 70 (DC Hochdorf to Geneva) would require significant operational adaptations. Since the demanded quantities of the stores on this route are comparably high, the shift in order picking would mean that the DC must shift its opening times.

¹⁸³ In the field production it has been shown that a strong distribution of lead times negatively affects the planning basis and thus, further performance parameters of a production system.

b) Time flexibility was qualitatively evaluated. The analysis shows that adaptations to the production concept influence time flexibility in an indifferent way according to the interpretation of the term ‘harmonisation’.

Shifting product generation times to enhance the time span to train departure increases the time flexibility of road carriers and DCs. Shifting product generation times according to train departure times and in the sense of reducing temporal buffers decreased time flexibility. Thus, the expected result should be reformulated to: *The enhancement of the time quota between production arrival times with the CT concept regarding train departures increases time flexibility.*

c) CT scenario II shows that in comparison with CT scenario I, the adaptation of the production concept improved SCP in terms of adherence to schedules. The analysis shows that the bigger the effect of adaptations, the longer the delivery windows. Although the average delays could be reduced from 2.03 hours to 0.73 hours, adherence to schedules was only improved from 28% to 41% (+/-15 minute delivery window) and from 39% to 55% (+/- 30 minute delivery window).

The discussions with the experts proved that this adherence to schedules is not sufficient for implementation in practice. For implementation, an adherence to schedules of at least 90% is required. These findings indicate that isolated adaptations of production concepts may not be sufficient for performance-oriented CT integration. Presumably, the integrated application of adaptations to different SC sub-concepts would be promising.

E₅: The (a) enhancement and the (b) harmonisation of store delivery windows with regards to the CT concept leads to (1) a reduction of lead times and (2) an improvement in adherence to schedules.

a) The impact of the enhancement of delivery windows was examined for all simulation scenarios. As expected, the simulation shows in all scenarios that the enhancement from a +/- 15minute to a 30 +/--minute delivery window positively influenced the adherence to schedules in a more than proportionate way. However, the enhancement of delivery windows means that capacities (e.g., for personnel and handling equipment for unloading, buffering and replenishment) must be held available, which may cause additional costs. Thus, this adaptation might be restricted to larger stores with a higher number of deliveries and personnel flexibility.

b) The harmonisation of store delivery windows with the CT concept, namely the train departure times, increased order lead times and improved adherence to schedules. The

effect was stronger the further the delivery windows were shifted backwards. This finding confirms a conflict in the SCP target system between lead time and adherence to schedules. The simulation study shows that shifting delivery windows improved adherence to schedules regarding too late deliveries nearly to the level of the basic scenario. For the enhanced delivery windows, 92% adherence to schedules was reached. Presumably to the disadvantage of lead times, the adherence to schedules could be further increased to reach the required level of practice implementation. Thus, the first part of the expected result cannot be confirmed. The simulation shows that the harmonisation of delivery windows with the CT caused an enhancement of lead times (because of an increase in order lead times).

E₆: The enhancement of delivery times leads to (a) increased lead times, (b) increased inventory levels, (c) improved adherence to schedules, (d) time flexibility and the (e) utilisation of transport vehicles.

a) + b) The analysis of CT scenario IIIa shows that the enhancement of delivery times increases lead times and thus inventory levels. The relationship between the increases in lead times and inventory was less than proportional.

c) Since the shift in target arrivals could not be directly modelled, it was assumed that the adherence to schedules could reach at least the level of the basic scenario. The ongoing transport route starts the next morning from the Dailens terminal. This transport route is compiled of comparably short route segments. It can therefore be assumed that there are only few possible delays and thus all deliveries are on time.¹⁸⁴

d) + e) As shown for E₁, time flexibility for all SC actors was increased by enhanced time buffers between scheduled events. Road carriers, terminal operators and CT operators in particular could improve their planning and thus their capacity utilisation.¹⁸⁵ As long as the product generation times are not adapted, it can be assumed that road carriers can improve utilisation capacities. However, this effect could not be shown by the simulation study. With regards to train capacities, the simulation shows that for the shifted product generation times, the capacities on single trains were used to the full. As explained before, this indicates that shifting deliveries to the next morning allows more balanced capacity utilisation.

¹⁸⁴ The effect on adherence to schedules could not be modelled.
¹⁸⁵ cf. Bendul (2009), pp. 170.

5.7.6 Limitations, Validity and Generalisability of Findings

The simulation model provides realistic data for the basic scenario, as well as for the integration of CT into the SC concept, as the discussions with the experts and the comparison with the as-is situation show. In the following section, the discussion of the restrictions and findings of the simulation study is accomplished in two steps. First, the restrictions in a narrower sense - focusing on the simulation model and the application scope - are discussed. Second, the findings are discussed in a wider sense - considering the previous findings of the thesis in hand, as well as the transferability and generalisability of the findings.

Internal and External Validity - Applicability of Suggested Adaptations to Practice

Several validation and verification steps were performed to improve the simulation's level of internal and external validity (cf. section 5.5.3). However, to reduce the complexity of the simulation model, several assumptions and simplifications were necessary. These aspects are discussed in relation to the background of the applicability and generalisability of results in practice. The restrictions discussed in this section do not influence the comparability of SCP between the different scenarios and thus the validity of identified cause-and-effect relationships. However, the restrictions must be considered to evaluate the generalisability and applicability of the findings for practical use.

The quality of a simulation model depends on the quality of the input data. The database provided by *Manor* is comprehensive and has a high level of detail. The iterative discussions with the experts allowed intensive validation and verification steps. The comparison of simulation results for the basic scenario showed a high level of similarity regarding SCP indicators. Thus, it can be stated that the simulation reached a high level of validity.

Emissions levels were calculated only for the transport processes. For a more detailed analysis, further considerations (e.g., on the necessary shunting and handling processes, as well as the specific transport vehicles and their current utilisation) would be required. The specific emission categories of the trucks as well as the propulsion modes (diesel or electricity) of the locomotives could be included to make the calculation more specific.

Lead transport times and *loading times* were calculated on the basis of transport distance and demand quantity. On the basis of the expert interviews, a conservative trans-

port speed of 50 km/h was assumed. Influencing parameters, such as congestion, technical disturbances, driving styles and break times were not modelled. Depending on the situation- and company-specific SCP requirements regarding adherence to schedules and accuracy of emissions levels, it would be necessary to assess the impacts of different transport routes (e.g., specific traffic situations and route-specific inclination profiles) and transport times (weekday and time).

SCP in terms of *flexibility* could only be evaluated on a qualitative basis. Here, the focus was on time flexibility that can be expressed by the possibility of short-term changes regarding times, quantities and destinations. For an encompassing evaluation of flexibility, further aspects, such as restrictions to advance announcements for the terminal and CT services, would be required. Furthermore, the SC concept's flexibility regarding disturbances in rail or road transport could be analysed in depth. For this, comprehensive further analysis would be necessary.

Also, the impact of CT integration on SCP regarding the *utilisation* of transport vehicles was evaluated qualitatively. The calculation of utilisation for the basic scenario and CT scenario I served as the basis. The SCP effect of transport route adaptations (in terms of the combinations of delivery stores per route) was not a central aspect of the research question. Although CT integration may encourage company- and situation-specific changes to transport routes, this aspect was not included in the simulation study. Further information on transport capacity planning and control of specific carriers would have been required to evaluate how many and which transport routes in the CT scenarios could be accomplished by a certain transport vehicle.

For the evaluation of utilisation, the utilisation on the first route segment served as the basis. However, in practice, the utilisation of a certain vehicle changes at each loading and unloading process. However, the discussion with the experts showed that this approach is acceptable and refers to practice. Nevertheless, the consideration of partial utilisation would open up the possibility to further improve capacity utilisation by changes to transport routes or by additional sites.

The calculation of *inventory levels* was performed only for the moment of product generation in the DC and the moment of unloading at the destination store. This provides restricted statements on the total SC inventory. Since production sites were not directly included in the simulation model, for a correct evaluation of the inventory levels, the production itself, the transport from production to DC and transport within the DC would need to be considered.

Exclusion of Stochastic Elements

The presented simulation model was setup without stochastic elements. Different demand quantities were modelled by four simulation runs with different demand levels per scenario. Additionally, different demand quantities per weekday were included. The exclusion of further stochastic elements and fluctuations offers the advantage that SCP effects can be directly referred to a certain adaptation of the SC concept. If stochastic elements were included, the researcher had to clarify, whether a certain effect results from the stochastic input data or from the characteristics of modelled SC concept. Furthermore, a high number of simulation runs was necessary to achieve a desired level of significance (cf. section 5.1.4). However, for a simulation study which is setup as decision support for CT integration, an inclusion including stochastic elements might be advisable depending on the specific framework conditions.

Despite these restrictions, the findings of the simulation study show a high level of internal and external validity. However, to apply the suggested adaptations and the calculated key figures in practice, limitations regarding generalisability must be considered. Several findings can be transferred to other industries, product groups and countries, but there are also limitations.

Generalisability and Transferability of Findings

The simulation study was set up with a limited scope of a lean SC concept and regular line transport on the basis of a retail distribution network. In the following section, the relevant differences between the chosen scenarios and other SC concept types, CT concept types, industries, product groups and countries are worked out to evaluate the generalisability and transferability of the findings.

Fluctuations in demand were modelled by four different demand situations. The discussion with the experts showed that in a retail SC, these situations are representative of standard delivery. However, extraordinary demand situations were consciously excluded. Thus, transferability to *agile and leagile* (downstream of the customer decoupling point) SC concepts, with highly fluctuating demands, is limited. The simulated SC concept was characterised by comparably short lead times. All priority goods were handled with a lead time below one day. The simulation shows that the enhancement of delivery times improves SCP-oriented integration. Thus, a transfer to other *lean SC concept* types (type I - plan and optimise and type II - continuous replenishment) would be, in general, possible.

This means that the findings are transferable to lean SCs in other industries and other

product types. Relations between a certain source and a certain destination with predictable and stable transport quantities and frequencies on a daily basis are suitable for transferring the findings.¹⁸⁶ Transport vehicles should be organised according to defined time schedules. This is the prerequisite for the regular booking of capacities on certain trains.

In the presented example, the gained advantages regarding emission levels caused the accepted lead time and inventory increases. However, for transferring results to other application fields, two main aspects must be considered. (1) The situation-specific *spatial configuration* of the SC concept is critical for CT integration. The availability of terminals and suitable CT services in the required start and destination region(s) must be given. (2) The specific product value affects the capital commitment due to inventories. In retail, the average value is comparably low (e.g., in comparison with the automotive and electronics industries). To transfer findings to other products and industries, the *relative value of goods* is central. For instance, in JIS deliveries, a lead time and inventory increase may not be acceptable, as the high-value goods may cause a significant increase in capital commitment.

Furthermore, the findings are transferable *to other CT concepts*. The suggested adaptations are also valid, but the resulting extra effort required for the adaptations must be weighed against the resulting advantages.

The simulation model was limited to a certain aspect of the conceptual model presented in chapter 4. The procurement concept was not modelled at all. Thus, no statements on the developed propositions can be made with regards to procurement. Also, it was limited to material flow processes. Information and financial flows were not modelled in the simulation. Thus, no statements can be derived on the intensity of the coordination effort required for an SC concept with unimodal road transport or for SC concepts with a CT concept. As a result, the impact of integrative measures and instruments could not be examined in the simulation model. These rather general limitations are comprehensively discussed in the concluding sixth chapter.

¹⁸⁶ Therefore, a network with several sources and destinations (as in the example SC) is not necessary.

5.8 Intermediate Findings

This section briefly summarises the main findings of the simulation study in the context of all the findings in the thesis in hand.

First, the simulation study sustains the findings of the previous chapters in the present thesis (under consideration of the presented limitations). It supports the main assumptions of the conceptual research framework. The simulation study proves that situation-specific adaptations to SC concepts open up time requirements for the CT integration, thus positively improving SCP in the case of a lean SC concept and for a regular line transport concept.

As a result of the number of validation and verification steps, the developed simulation model was suitable for the analysis of cause-and-effect relationships between elements of the CT and SC concepts, although several assumptions and simplifications were necessary to keep the model's complexity low.

The comparison of the four different scenarios and for different demand situations pointed out target conflicts in the key figures of the SCP system. In particular, the connection between the targets for lead times and inventory level reductions and the improvement of adherence to schedules and flexibility turned out to be central for CT integration.

It could be demonstrated that CT integration leads, as expected, to an enhancement of lead times. However, a disproportional effect on inventory levels, adherence to schedules and time flexibility was evident in the simulation study. The reasons for this connection were the defined and comparably seldom train departure times. In contradiction with unimodal road transport concepts, in which a few minutes delay at loading or transport usually causes a few minutes delay at delivery, in a CT concept, a few minutes delay in loading or transport may cause several hours delay at delivery, since missing a designated train increases delay times.

The same explanation is valid for the unexpected results for the harmonisation of delivery windows and production times with the CT concept. The synchronisation, namely a reduction of time quotas between events in the SC (e.g., between production generation, order picking, loading and delivery windows), caused a reduction in adherence to schedules. Whereas a reduction of average lead times could be observed, the expected positive effect on adherence to schedules and time flexibility could not be confirmed.

This finding encourages discussion of the appropriate level of harmonisation and integration. Referring to the findings on vulnerability in integrated SCs (cf. section 2.1.4), the simulation study indicates that an overly strong temporal integration of material flow endangers SCP regarding the rather innovative key figures of adherence to schedules and flexibility. In general, the simulation indicates that '*deceleration*', rather than a focus on decreasing lead times, reduces the vulnerability of the SC and thus supports the integration of performance-oriented CT into SC concepts.

As a result, it can be stated that adaptations to the SC concept regarding the CT concept positively influence SCP, but that a situation- and company-specific choice and weighting of key figures is the prerequisite for success.

Finally, the analysis indicates that integrated adaptations to different SC sub-concepts are promising with regards to improving the performance level of the SC concept including unimodal road transport. Thus, performance-oriented CT integration requires cross-functional cooperation. However, this again indicates that for applicability in practice, also the managerial and behavioural aspects of the integration problem (cf. section 2.1.5) are both highly significant for CT integration.

A discussion of the results with regards to the previous findings of the thesis in hand, in particular with reference to the conceptual research framework and the propositions, follows in the concluding chapter.

6 Implications for Science and Practice on the Performance-oriented Integration of CT into SC Concepts

This thesis addresses the question, of how CT can be integrated into SC concepts with regard to the target system of SCP (main research question Q_0). The thesis was able to develop an approach for the structured description of SCP requirements regarding the embedded and linking transport concepts (research question Q_1). Additionally, a conceptual framework for the description of cause-and-effect relationships between the elements of SC and CT concepts was developed (research question Q_2). The impact of integrative measures and instruments on the fit between SC and CT concepts was discussed with regard to the target system of SCP and practical recommendations on the application of the measures were derived (research question Q_3). This section addresses the central managerial (section 6.1) and practical implications (section 6.2). Furthermore, the most important limitations and future research perspectives (section 6.3) are highlighted.

6.1 Management Implications

The thesis in hand gives practical recommendations on the performance-oriented integration of CT into SC concepts. It highlights the performance-oriented applicability of CT in general for all SC actors. First, the thesis outlines the need to find alternatives to unimodal road transport and to reduce the related vulnerability of SCs. Second, the thesis discusses the main challenges of integrating material and information flow processes in SCs including CT. Third, it introduces solutions for the configuration of SCs including CT with regard to SCP. Fourth, by means of a simulation study the thesis shows the applicability of findings for practice and quantifies the SCP effect of SC concept adaptations for the analyzed SC concept.

Meaning of SCP as an Innovative Target System for all SC Actors

The thesis discusses SCP as a target system for all SC actors that can deal with the internal and external challenges of SC concepts. Therefore, a target system and corresponding performance indicators are developed, which allow for the evaluation of strategic and operative aspects of the integration problem. The developed target system comprises emissions, flexibility and reliability aspects next to 'classical' key figures such as lead time, capacity utilisation and inventory level. For managers, the thesis reveals that the changing framework conditions of SCs will prospectively require an

alternative weighting of these target dimensions. Thus, the thesis presents an innovative evaluation system for integration activities in the field of transport. Furthermore, it shows that CT can be integrated to increase the reliability and sustainability of a SC and to accept an increase in lead times, inventories and costs instead.

The simulation study indicated that the cause-effect-relationships between the elements of CT and SC concepts are often non-linear. For managers two main findings are central: (1) Different cause-and-effect relationships have to be considered for a SC concept including a CT concept and a SC concept including a unimodal road transport concept. (2) In a SC concept including CT, the reduction of time quotas between the events in the SC affect the adherence to schedules and flexibility of the SC concept in a more than proportionate way. Thus, the aspect of '*deceleration*' might be central for the discussion regarding the weighting of target dimensions.

Changing Shippers Perspectives - Transport as a Guiding Factor for SC Concept Configuration

The thesis in hand highlights the meaning of transport concepts as linking and embedded elements in SC concepts. The impact of transport concepts for the close integration of material and information flow processes and thus, for SCP is accentuated. This research suggests a perspective change regarding the meaning of transport concepts in SCs in general. The thesis is based on the idea that the transport concept is not a 'servant' to the SC concept, but a central element. Therefore, the thesis presents an approach to an innovative perspective on the integration problem. It suggests treating CT with its several inherent and external complexity factors as the guiding factors for SC concept configuration. This means that the procurement, production and distribution concepts have to be adapted to the CT concept to improve SCP.

A simulation study on a lean SC shows that the adaptation of the SC concept configuration with regard to a given and non-adaptable CT concept allows increasing SCP not only with regard to reliability and sustainability, but also – depending on the situation-specific framework conditions – reaching the performance level of unimodal road transport, too.

Different Implications for Different SC Actors

The thesis in hand takes a rational and non-actor-specific research perspective. Thus, different implications for different SC actors can be derived.

The thesis highlights the performance capabilities of CT services for *shippers*. Many shippers still do not consider CT as an alternative to unimodal road transport. The

promising results of the thesis should encourage shippers to consider CT as a competitive alternative for meeting the requirements of a new performance orientation in corporate and SC target systems. Additionally, shippers are advised to change their understandings of transport concepts as the 'servants' of the procurement, production and distribution concepts. Therefore, the thesis presents a set of practical recommendations on the choice of a suitable CT concept. In a first step, it recommends orientating to the underlying SC and the specific integration point in the SC. In particular, lean and agile SC concepts are suitable for CT integration because of the underlying high level of demand predictability or comparably long lead times. The higher, more frequent and more stable transport quantities are the more line transport with regular booking can be applied. However, for rather fluctuating transport quantities with long lead times, line transport concepts with flexible bookings are suitable. Packaged goods with comparably long lead times can be handled by CT networks. Despite these rather general fits between the SCP requirements of SC concepts and performance characteristics of CT concepts there can be significant differences in certain SCP requirements. In a second step, based on an empirically developed classification of SCP requirements, the selection of practical recommendations on adaptation points in the procurement, production and distribution concepts are proposed to improve the fit and allow performance-oriented integration. In a third step, the thesis introduces a selection of concrete integrative measures and instruments to improve the integration of material and information flow processes to increase SCP and to reach competitiveness with unimodal road transport, even regarding classical key figures such as lead time and costs.

The thesis encourages the communication of the benefits for all SC actors by showing the potential for improved SCP from CT integration. *CT actors*, such as rail carriers, terminal operators or CT operators, are encouraged to communicate that CT is a competitive alternative to unimodal road transport. CT actors must use ongoing changes in the SC environment, such as increasing energy prices, SC vulnerability and sustainability orientation, to explain that CT may prospectively lead to a higher level of SCP. This means that CT actors have to change their own understandings in terms of integrated SC actors, too. Thus, the thesis in hand invites CT actors to free the transport concept from its role as 'servant' to SC concepts. CT actors must focus their activities on the main SCM target, namely the end customer. This requires that CT actors improve their understandings of shippers' operative challenges. The results of the thesis in hand allow CT actors to show shippers not only performance potential, but also the concrete adaptation points and instruments to reach it. In other words, it invites CT actors to become more than 'just transport actors'. The thesis encourages CT actors to advise

shippers regarding the choice of suitable CT concepts, the necessary adaptations to the SC concept and the usage of integrative measures and instruments to allow performance-oriented CT integration.

For *transport policy*, the thesis highlights the impact of political regulations and support for transport concepts in general. In particular, the thesis accentuates the political influence on the competitive situation with unimodal road transport. Thus, the thesis in hand encourages transport policy to create a stable and long-term planning basis for all companies. The suggested perspective change emphasises the need for a long planning horizon since the thesis shows the strategic dimension of transport mode choice as well as material and information flow integration. Since SCs including CT are often international, the thesis also encourages a European and international aligned transport policy to provide suitable infrastructure capacities of road, train paths and terminals.

Structured Description of SCP Requirements on Transport Concepts

The thesis has shown that SC and CT actors have a limited mutual understanding of operative challenges, problems and target systems. Therefore, it presents a structured approach to describe shippers' SCP requirements regarding transport concepts with seven performance dimensions. The approach is not restricted to the field of CT and can be applied to any type of transport concept. Both SCP requirements of a SC concept and SCP capabilities of a transport concept can be described. It allows the comparison of requirements of a certain SC concept with the capabilities of a specific CT concept and supports the identification of specific adaptation points and integrative measures. Up to now, no structuring approach for transport concept integration has been available. Thus, the structuring approach serves to increase the mutual knowledge of the requirements on the transport concept to reach a close integration of material and information flow processes.

The thesis in hand shows the need for action by all SC actors by showing recent and prospective challenges of SCs and approaches.

6.2 Scientific Implications

The thesis in hand presents the deductive and theory-guided development of a conceptual research framework on the performance-oriented integration of CT into SC concepts.

Enhancement of SCM Conception - Transport Actors as Integrated SC Actors

In this context, the research proves that the conception of SCM is still in need of improvement. CT actors are not perceived as integrated SC actors. Hence, this research closes the identified research gap at the interface between transport and SCM. The thesis generally highlights the meaning of transport concepts for SCP and provides an approach for the structured description of SCP requirements.

Development of a Conceptual Research Framework

Based on this understanding, the research in hand develops a complete conceptual research framework on the performance-oriented integration of CT into SC concepts. With regard to the novelty and complexity of the given research problem, the thesis takes a rational and non-actor-specific research perspective. Configuration theory reflects the complexity and chosen research perspective. It serves as the basis for the conceptual research framework. There are already publications on configuration theory in the context of SCM, but the thesis in hand transfers configuration theory to the new field of CT. A complete conceptual research framework describes all relevant aspects and the main cause-and-effect relationships for the research problem (cf. section 4.2.3). The three-fold research framework breaks down the research problem into partial problems and transfers rather abstract constructs to measurable and observable variables.

The developed research framework states that the alignment of SC concepts with regard to the CT concept improves SCP. Therefore, the thesis develops material and information flow-oriented typologies for SC and CT concepts. Furthermore, a description structure for SCP requirements and performance capabilities as well as a set of suitable performance indicators is presented. These performance indicators regard the comparably new performance orientation and consider reliability and sustainability aspects. Thus, from a scientific point of view, the thesis contributes to transferring the comparably new research field of SCP management to the field of transport, especially CT.

The framework demonstrates the way to deal with the research problem and with the SC concept as the configuration variable as well as the CT as the framework variable. The developed framework serves as a visualisation of the innovative perspective on the research problem of the thesis in hand. It is enhanced by integrative measures and instruments as the 'moderating variable'. The basis was a comprehensive and structured literature review for integrative measures in the field of SCM. The literature provides an innovative overview of publications in the field of integration research with a focus

on technical and organisational aspects.

The conceptual research framework is implicitly based on rather general propositions on the effect of CT integration into SCs. These propositions serve as initial points for further research. Applying configuration theory, the propositions are developed to an encompassing and complete set of cause-and-effect relationships for the integration of CT into SC concepts.

Next to these managerial and scientific implications, different limitations of the thesis in hand must be considered.

6.3 Limitations and Further Research

The discussion of the contributions of the thesis in hand must be accompanied by its limitations. These limitations relate to the research perspective, simplifications of the conceptual research framework and methodological limitations regarding the need for a qualitative and quantitative verification of findings in general and the limitations regarding the applied simulation methodology in particular.

Limitations to Technical and Organisational Aspects of the Integration Problem

Sustainability and reliability are recent key figures in the target system of SCP to which companies align their activities. Rising transport costs, caused by increasing energy prices and political regulations, may prospectively further shift the competitive situation between unimodal road transport and CT in favour of CT.

Owing to the novelty of the research field, the thesis in hand aims to highlight the potential of CT integration. This potential orientation is reflected by the neutral and non-actor-specific research perspective. This perspective corresponds to the central idea of SCM conception. Thus, it focuses on the technical and organisational aspects of the integration problem, rather than on the behaviour- and management-specific aspects. This restriction reduces the problem complexity, but strongly simplifies the problem. This means that the thesis in hand does not discuss actor-specific considerations supporting or against a close integration of material and information flow processes. Furthermore, the thesis does not include recommendations on the management of such an integrated SC.

Thus, for the application in practice, management methods, the power and relationship structure, the risk structure as well as cultural aspects have to be considered next to the rather technical considerations presented in the thesis in hand. According to Cooper (1997), these aspects have the same relevance for reaching SCP as the technical as-

pects do.¹ This reduction of the integration problem to material and information flows and thus, technical and organisational aspects is the main limitation of the thesis in hand. For further research, the managerial and behavioural aspects must be analysed in depth and quantified.

Scope of SC Integration

The thesis in hand assumes that the integration of all CT and SC actors is beneficial. However, the comprehensive integration of all business partners is not always reasonable from an economic point of view, because some relationships are only of short-term character. Furthermore, transaction costs must be taken into consideration for the development of all cooperative relationships. The variety of publications on dyadic cooperation proves that the management of one-to-one relationships is already a demanding task. Thus, for future research, the scope of SC integration must be challenged. Therefore, an actor-specific perspective is necessary. In particular, the application of transaction cost theory is advisable for this task. Taking an actor-specific research perspective, a number of further theoretical approaches can be analysed regarding their contributions to the problem of CT integration.

Simplifications for the Development of the Conceptual Research Framework

The development of the conceptual research framework required several simplifications. Based on configuration theory, the typologies of SC and CT concepts are analysed regarding their mutual 'fit'. It is assumed that a SC concept can be described by the configuration of the embedded procurement, production and distribution concepts. To reduce the complexity of the analysed cause-and-effect relationships process manufacturing² was excluded from consideration. Thus, the transferability of the findings must be analysed beginning with a comprehensive description of the characteristics of process production. Following the restriction to the technical and organisational aspects of the research problem, it was assumed that this fit could be described by the description approach with seven performance dimensions. The consideration of the behavioural and management aspects of the integration problem would require the enhancement of the developed description approach.

The thesis points out a number of framework conditions that influence and often exac-

¹ cf. Cooper et al. (1997).

² Production of goods in bulk quantities, rather than discrete units.

erbate the integration of CT into SC concepts. The framework summarises these framework conditions as 'SC strategy' and 'SC environment'. Whereas the thesis in hand deeply considers the meaning of SC strategy, further framework conditions are only touched. The meaning of changing shippers' requirements and transport policy for CT have been discussed in general, but a comprehensive determination of the influence of different conditions is missing. Further framework conditions, such as general aspects related to country and specific aspects such as the characteristics of other SC actors, competitors or customers, are excluded. An exploratory analysis, for instance using case studies, is recommended to identify and quantify the impact of different environmental factors. Thus, the conceptual research framework leaves room for further research, which should aim at the identification of the additional relevant elements for performance-oriented CT integration and a validation of the propositions and cause-and-effect relationships.

Methodological Limitations

For the thesis in hand, a combined inductive-deductive research approach was chosen. The predominant conceptual part of the thesis is enhanced by a simulation study that delivers information on inductive interpretation. In the field of SCM, experiments are often not possible because material and information flow processes cannot be interrupted. Furthermore, the novelty and complexity of the given research problem prevent the accomplishment of a quantitative empirical analysis of the research problem. Thus, a simulation approach was chosen to validate and enhance the selection of the deduced findings. However, a simulation cannot replace the empirical testing of deductively gained hypotheses. Thus, for further research, the quantitative review and empirical testing of the conceptual research framework, propositions and cause-and-effect relationships are necessary. The empirical analysis should build on the developed framework and should aim at the explorative generation of empirical knowledge. In particular, the suggested integrative measures and instruments as well as the framework conditions and the chosen performance indicators must be challenged and enhanced.

Limitations of the Simulation Study

The conducted simulation study is based on empirical data provided by *Manor*, a big Swiss retailer. The object-oriented and discrete event simulation encompassed two DCs in central Switzerland and eleven stores. The target of the simulation was the evaluation of SCP using a defined set of deductively developed performance indicators. The effect of CT integration in general and the effect of specific SC concept adaptations in

the production and distribution concept were analysed. These adaptations refer to the propositions and cause-and-effect relationships presented in the conceptual research framework.

Scope of the Simulation Study

The setup of the simulation study does not cover all aspects of the conceptual research framework, namely the simulation study is limited to lean SCs (type I - continuous replenishment) and the CT concept of line transport with regular bookings. The influence of the integrative measures and instruments is not included at all. Furthermore, only adaptations of the production and distribution concept were analysed in the simulation in order to reduce the complexity of the simulation model. Thus, the results derived from the simulation study can be generalized only to a certain extent.

The simulation study presented in the thesis in hand is based on the terminal network of *Swiss Post*. This means, for a generalisation of results the influence of central framework conditions must be discussed. Despite the growing importance of sustainability and reliability, reality proves that costs are still a central factor for transport mode choice. *Swiss Post* offers CT services with a comparable cost level to unimodal road transport. The reason is the *Swiss Post's* effort to increase the capacity utilisation of existing terminals, overheads and trains. Thus, in this example the competitive situation with unimodal road transport is shifted in favour of CT.

Assumptions and Simplifications

The simulation is based on several assumptions and simplifications. These aspects must be taken into consideration when generalising the results. These simplifications encompass for instance the speed of road transports, duration of handling times, emission factors as well as demand quantities. Furthermore, a number of assumptions were necessary for the calculation of performance indicators (cf. section 5.7.6 for a comprehensive review of the impact of simplifications and assumptions on simulation results). However, a number of validation and verification steps ensures a high level of validity of the simulation's findings. Limitations of the simulation study are shortly discussed regarding their impact on the transferability and generalisability of simulation results.

The applied target system for the simulation study does not include the consideration of transport costs. The calculation of transport costs depends on a number of company-specific and competition-relevant information. Furthermore, the calculation of costs must be understood as a snapshot of the recent framework conditions since volatile energy prices and tolls are included in the calculation. A profitability analysis is central

for the decision making process on CT integration in practice.

To reduce the complexity, the model does not encompass the material flow processes in the stores. It is assumed that the goods leave the system as soon as the transport reaches the store and there is an open delivery window. Furthermore, no production sites are included in the model, but the goods' generation is modelled to take place in the DC. Although this simplification allows analyzing different adaptations of production concepts, for an evaluation of the inventory in the entire SC concept, inventories in production, on the transport between production and in the DC must be included in the calculation of SC inventory. The order lead time, too, is abbreviated in comparison with the real system. However, for a comparison of the unimodal road transport scenario with different CT scenarios these simplifications are acceptable, since they do not influence the relations of the performance indicators.

Transferability and Generalisability of Simulation Results

The findings of the simulation study are transferable to lean SCs in other industries and other product types. Relations between a certain source and a certain destination with predictable and stable transport quantities and frequencies on a daily basis are suitable for transferring the findings. However, for transferring results to other SC concept, two further aspects must be considered. (1) The situation-specific *spatial configuration* of the SC concept is critical for CT integration. The availability of terminals and suitable CT services in the required start and destination region(s) must be given. (2) The specific product value affects the capital commitment due to inventories. In retail, the average value is comparably low (e.g., in comparison with the automotive and electronics industries). To transfer findings to other products and industries, the *relative value of goods* is central. Furthermore, the findings are transferable *to other CT concepts*. The suggested adaptations are also valid, but the resulting extra effort required for the adaptations must be weighed against the resulting advantages.

In total, the simulation study supports the findings of the conceptual research framework. Furthermore, it reveals several non-linear cause-and-effect relationships between the elements of CT and SC concepts. Additionally, the simulation study indicates that the scope of SC concept adaptations to the CT concept is critical. It could be shown, that temporal buffers can be exploited for CT integration, but have also an important role for the stability of SC concepts. Thus, it can be summarized that for the reduction of temporal quotas and the harmonization of SC and CT concepts the situation-specific framework conditions and the resulting situation-specific cause-and-effect relationships must be considered.

Outlook and Limitations of Configuration Theory

Configuration theory was applied as a framework for the problem solution process.

CT integration influences other company and SC fields. These impacts must be considered for the integration decision. Usually, a company has more than one SC. The adaptation of one transport concept to CT can influence other SCs. The impact on other corporate departments, such as marketing, should be taken into consideration. The integration of CT and the suggested adaptation of SC concepts may significantly influence the existing relationships with suppliers and service providers. Trust and experience are central to these relationships. These aspects may compensate for the positive performance effect of CT integration.

Configuration theory implies working with typologies. This causes the danger that the defined variable settings are rather ideal than real. Furthermore, the usage of typologies risks that the research does have a comparably low level of detail. This means for prospective research that the typology of the CT concept must be reviewed and enhanced in more detail. However, one central criticism of configuration theory is that a falsification of typologies is not possible.³ For instance, a classification according to regional character such as domestic, hinterland and international transport would be sensible. One disadvantage of configuration theory is that it does not make recommendations on the type or number of suitable variables for the definition of typologies.⁴

Configuration theory suggests using longitudinal analyses to identify the structure and direction of cause-and-effect relationships. This means that the evaluation of CT integration using a simulation study was suitable to analyse the effect on SCP for a longer period. Thus, prospective research might focus on exploratory and longitudinal case studies. The danger of this approach is the allocation of cause and effects since recent events are usually the results of previous activities.⁵

³ cf. Wolf (2008), p. 481.

⁴ cf. Ibid., p. 482.

⁵ cf. Ibid., p. 480.

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Appendix

Appendix A	349
<i>A-I List of Conducted Expert Interviews for Development of SCP Requirements Classification</i>	
<i>A-II List of Conducted Interviews for Simulation Study Development</i>	
Appendix B –Simulation Model - Demand per Store and Weekday for Non-prioritized Goods	351
Appendix C – Activity Diagrams – Simulation Study	352
<i>C-I - Sequence of Model Configuration</i>	
<i>C--II - Sequence of Simulation Runs</i>	
Appendix D –Simulation StudyData Pool (CD)	354

Appendix A

A-I List of Conducted Expert Interviews for the Development of the SCP Requirements Classification

surname	name	position	company	main location	date
Ackermann	Josef	CEO	Swissmill	Zurich	April 30, 2009
Andenmatten	Walter	Head of Logistics	Manor	Zurich	November 11, 2009
Arnold	Josef	CEO	Zuckerfabrik Aarberg und Frauenfeld AG	Frauenfeld	April 30, 2009
Beutler	Martin	Executive	Fenaco	Bern	July 2, 2009
Buchs	Marius	Head of Logistics	Tetrapack	Lausanne	November 9, 2009
Deutschmann	Rainer	Member of the Management Board	Manor	Zurich	April 28, 2009
Flück	Marlene	Head of Logistics	Mibelle AG	Buchs	October 2, 2009
Häfliger	Luigi	Member of the Executive Committee	Fiege Schweiz	Bern	April 29, 2009
Hartl	Dr. Rolf	CEO	Erdölvereinigung	Zurich	April 29, 2009
Hungerbühler	Peter	Head of Logistics	KVA Thurgau	Weinfelden	November 2, 2009
Imhof	Dr. Marcel	CEO	Schmolz & Bickenbach AG	Dusseldorf	April 8, 2009
Kerr	Barbara	Head of Logistics	Coop	Basel	October 28, 2009
Krattiger	Moreno	CEO	Panlog	Emmenbrücke	April 8, 2009
Lindenblat	Dr. Dieter	CEO	Thyssenkrupp Verkehr GmbH	Duisburg	May4, 2009
Menzi	Urs	General Manager	Eternit AG	Niederurnen	June 29, 2009
Metzger	Bernhard	Head of Logistics	Migros	Zurich	November 30, 2009
Runge	Lars	Engineering	SF-Chem AG	Pratteln	June 30, 2009
Schwendener	Edwin	Head of Logistics	Alcan Airex AG	Altenrhein	June 29, 2009
Thaler	Hugo	Head of Logistics	Bischofszell Nahrungsmittel	Bischofszell	November 30, 2009
von Rotz	Josef	Head of Procurement	Swissmill	Zurich	November 6, 2009
Walt	Ulrich	Head of Logistics	Holcim	Zurich	October 16, 2009
Zingg	René	Business unit Manager Logistics	Geiser agro.com AG	Langenthal	July 1, 2009
Zurflüh	Christian	Head of Operations	Manor	Zurich	November 3, 2009

A-II List of Conducted Interviews for Simulation Study Development

surname	name	position	company	location	date
Andermatten	Walter	Head of Import and Supply Chain	Manor	Basel	August 11, 2011
Bürge	Rene	Head of Site Logistics	Swiss Post, Post Logistics	Frauenfeld	May 16, 2011
Deutschmann	Rainer	Member of the Management Board	Manor	Olten	April 5, 2011
				Basel	August 11, 2011
Ernst	Thomas	Head of System	Swiss Post, Post Logistics	Zurich	March 28, 2011
Fiechter	Stefan	Head of CombinedTransport	Swiss Post, Post Logisitcs	Härkingen	April 26, 2011
Koch	Oliver	Head of DC Hochdorf	Manor	Basel	August 11, 2011
Schürmann	Markus	Head of DC Möhlin	Manor	Basel	August 11, 2011
Zurflüh	Christian	Head of Operations	Manor	Olten	April 14, 2011
				Basel	April 5, 2011
				Basel	August 11, 20011

Appendix B –Simulation Model - Demand per Store and Weekday for Non-prioritized Goods

		Monday	Tuesday	Wednesday	Thursday	Friday	generation time
DC HOV	CHA	3	3	4	3	3	11:00 AM
DC HOV	GEN	20	19	24	18	19	10:00 AM
DC HOV	LAU	2	4	4	3	4	10:20 AM
DC HOV	MON	2	0	6	3	2	12:00 AM
DC HOV	MOR	1	1	0	3	1	11:00 AM
DC HOV	NYO	1	0	0	3	1	11:00 AM
DC HOV	SIE	3	1	0	14	6	9:00 AM
DC HOV	SIO	3	1	0	12	5	9:00 AM
DC HOV	VEV	3	6	6	5	5	10:20 AM
DC HOV	VES	1	1	1	0	2	8:00 AM
DC HOV	YVE	1	2	0	0	4	3:10 PM
DC MOE	CHA	7	10	8	9	8	9:15 AM
DC MOE	GEN	22	28	25	28	23	7:45 AM
DC MOE	LAU	9	13	10	12	11	8:15 AM
DC MOE	MON	6	0	14	6	6	8:10 AM
DC MOE	MOR	6	6	0	14	6	9:15 AM
DC MOE	NYO	2	3	0	5	4	7:05 AM
DC MOE	SIE	2	3	0	4	6	7:20 AM
DC MOE	SIO	2	3	0	4	7	7:25 AM
DC MOE	VEV	7	7	9	8	8	8:20 AM
DC MOE	VES	2	4	3	0	5	4:30 PM
DC MOE	YVE	3	6	3	0	9	11:45 AM

Appendix C – Activity Diagrams – Simulation Study

C-I - Sequence of Model Configuration

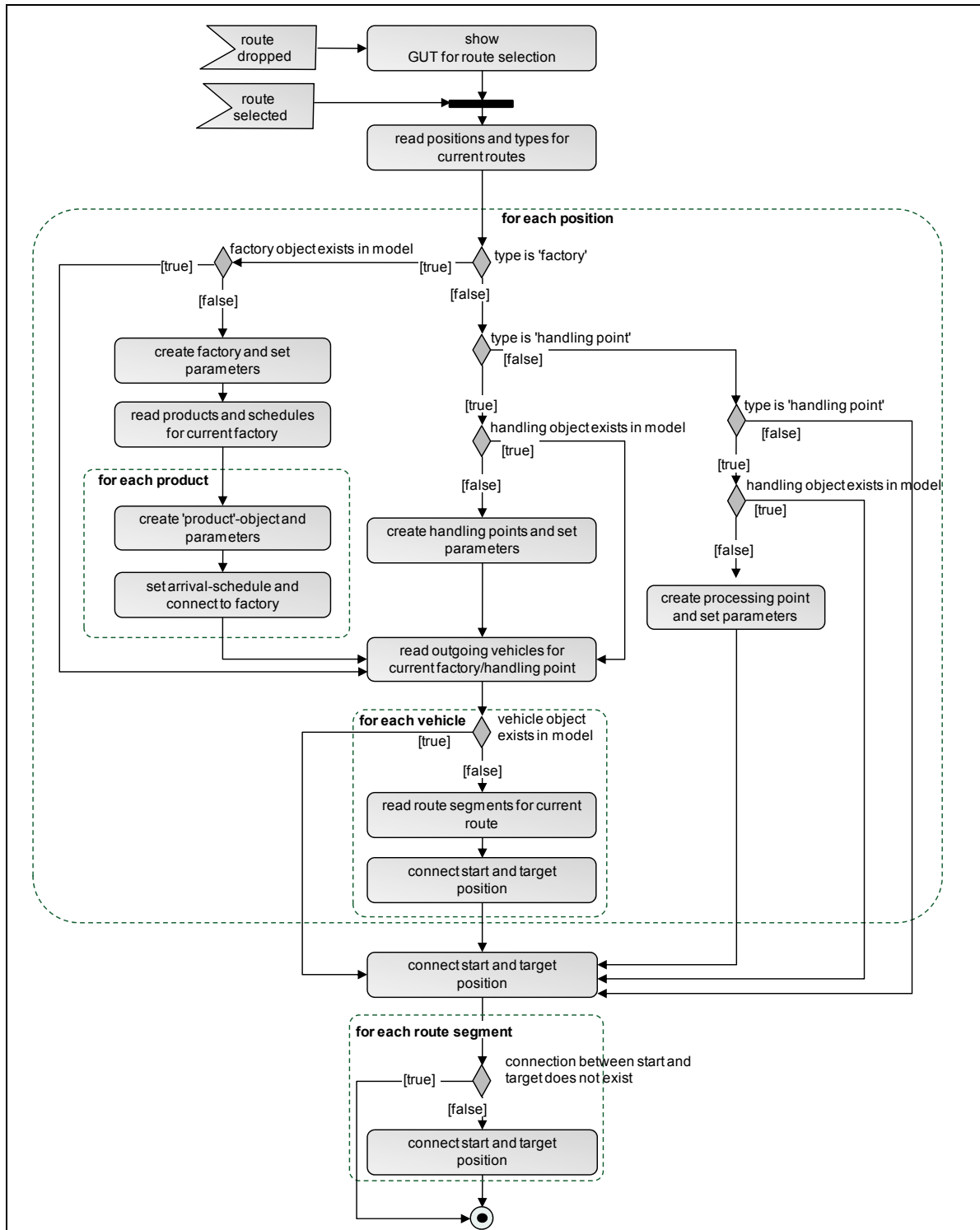


Figure Appendix - 1: Activity diagram in UML notation for model configuration.

C--II - Sequence of Simulation Runs

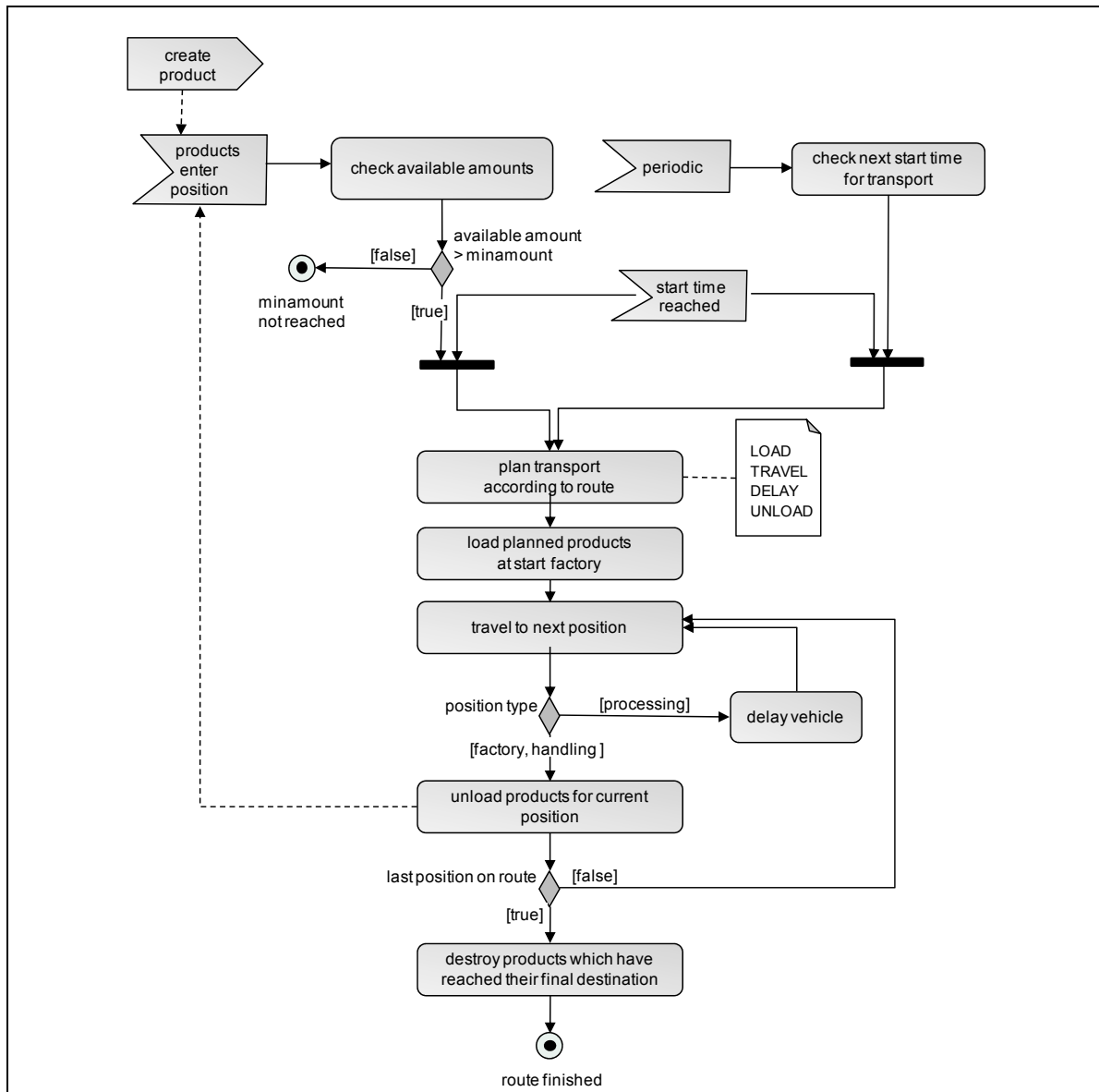


Figure Appendix - 2: Activity diagram in UML notation for simulation run.

Appendix D – Simulation Study Data Pool (CD)

The attached CD includes all relevant input data, output data as well as the developed simulation model.