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New business model for horizontal supply chain collaboration in the commodity industry
a European explorative case study for styrene monomer

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New business model for horizontal supply chain collaboration in the commodity industry
A European explorative case study for styrene monomer

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Abstract

This report describes a new business model for horizontal supply chain collaboration in the commodity industry. Based on the learnings of four case studies, we propose a set-up via an independent ‘black-box’ party, 4C4Com, that optimizes transport flows over the entire pool of participants by physically bundling volumes, swapping volumes geographically and having the opportunity to invest in intermediate storage facilities. We develop a mixed integer linear programming (MILP) model able to calculate the strategic business case for such a collaboration, optimizing total transport, storage and inventory holding costs. CO$_2$ savings can be calculated using the output of this model. The MILP model is solved in a case study of the European styrene monomer industry performed at Shell Chemicals Europe B.V.. We showed substantial cost and CO$_2$ savings are possible and obtained valuable insights into the drivers of these savings. Yet more products, preferably of which available supply is spread over Europe, need to be included before the concept is truly viable.
## List of abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>3PL</td>
<td>Third Party Logistic Provider</td>
</tr>
<tr>
<td>4C4Com</td>
<td>4C4Commodity</td>
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<tr>
<td>4PL</td>
<td>Fourth Party Logistic Provider</td>
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<tr>
<td>abs.</td>
<td>Absolute</td>
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<tr>
<td>ATI</td>
<td>Antitrust Immunity</td>
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<tr>
<td>B.V.</td>
<td>“Besloten Vennootschap” (Dutch legal entity, similar to an Ltd.)</td>
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<tr>
<td>CH</td>
<td>Clearing House</td>
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<tr>
<td>Dinalog</td>
<td>Dutch Institute for Advanced Logistics</td>
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<tr>
<td>FTL</td>
<td>Full Truck Load</td>
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<td>HSCC</td>
<td>Horizontal Supply Chain Collaboration</td>
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<tr>
<td>HSSE</td>
<td>Health, Safety, Security &amp; Environment</td>
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<tr>
<td>JV</td>
<td>Joint Venture</td>
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<tr>
<td>GDS</td>
<td>Global Distribution System</td>
</tr>
<tr>
<td>KT</td>
<td>Kilotons</td>
</tr>
<tr>
<td>LBI</td>
<td>LyondellBasell Industries</td>
</tr>
<tr>
<td>LSP</td>
<td>Logistic Service Provider</td>
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<tr>
<td>mT</td>
<td>Metric ton(s)</td>
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<tr>
<td>MILP</td>
<td>Mixed Integer Linear Programming</td>
</tr>
<tr>
<td>N.V.</td>
<td>“Naamloze Vennootschap” (Dutch legal entity, similar to a limited liability company)</td>
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<tr>
<td>rel.</td>
<td>Relative</td>
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<tr>
<td>RTC</td>
<td>Rail Tank Car</td>
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<tr>
<td>SCE</td>
<td>Shell Chemicals Europe</td>
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<td>SC</td>
<td>Supply Chain</td>
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<td>TC</td>
<td>Transport Costs</td>
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Management Summary

In this report we present the results of a master thesis relating to one of the three 4C4Chem research projects aimed at horizontal collaboration in the chemical industry, initiated by the Dutch Institute for Advanced Logistics, Dinalog. Horizontal collaboration is active cooperation between two or more firms operating on the same level of the supply chain. This particular research project was carried out at Shell Chemicals Europe (SCE) B.V. in Rotterdam.

Problem statement

4C4Chem is driven by a desire to reduce transport flows in Europe, which have received considerable attention due to tight margins, environmental concerns, congestion and the foreseen reduced availability of long distance drivers over the next five years. About 10 per cent of these transport flows is caused by the chemical industry. Transport accounts for a large percentage of the total cost to serve some of the customers for those chemicals due to large distances, movements of relatively small volumes or inconvenient connections to preferred transport means.

There is a huge potential to be achieved through collaboration between producers, customers, suppliers and service providers to drive out waste and cost in the chemical industry [The European Petrochemical Association, 2007]. Horizontal supply chain collaboration (HSCC) in the commodity industry in particular, has additional potential compared to ‘ordinary’ products since commodities are considered interchangeable. Hence, to investigate possibilities for improving the supply chain efficiency of the commodity business, the following problem statement was defined:

What innovative business model for horizontal supply chain collaboration in the commodity industry can be developed that improves overall supply chain efficiency and what is the corresponding business case for a European explorative case study in the styrene monomer industry?

Business Model

Based on the learnings of 4 case studies we performed for companies/projects applying some related form of HSCC (the Clearing House project, Tri-Vizor N.V., ARG and SkyTeam), we designed a new, innovative business model for an independent ‘black-box’ entity: 4C4Com. 4C4Com enables HSCC between structural shippers of commodities in Europe, i.e. either producers that locally produce more than they consume or structural importers. These shippers need to ship a true commodity that is not transported mainly via pipeline. The total size of the shipments should be significant, at least initially, and the supply chains of the collection of shippers should be compatible. In order to make HSCC attractive, shippers should moreover experience high transport costs for a significant part of their orders, whether this is caused by a large spread of customers, inconvenient connections to preferred logistical means or transport of relatively low volumes. Finally, when it is desirable to optimize based on distance between the source and the destination of the product, the availability of it should be spread over Europe (i.e., the only criterium not being met by styrene, nor any other product is currently produced
by SCE B.V. that meets all criteria). Note that these criteria for shippers can be directly translated to criteria for products that may benefit from HSCC.

4C4Com allows the structural shippers meeting at least the first five criteria to optimize logistic costs and CO\textsubscript{2} emissions, operating based on the main principle that the total supply made available to it must meet the total corresponding demand handed over to it. This implies total demand of a customer needs to be met, no matter by what supplier(s) this is physically supplied. Original sales relations remain intact. 4C4Com collects information from all individual shippers and optimizes over the entire chain. The main principle allows 4C4Com to physically bundle volumes, swap volumes geographically and to combine by opening shared storage facilities. By geographical swaps we mean 1 or 2 rather than all shippers supply an entire destination (ensuring the other shippers supply other destinations), because bundling or location effects favour to do so. Figure 1 shows the intended concept in terms of information flows, financial flows and contracts. 4C4Com holds all transport contracts and allocates transport costs incurred to supply the original customers of the suppliers, increased with operating costs of 4C4Com, according to some fair gain sharing mechanism.

![Figure 1: The concept of 4C4Com](image)

**Optimization Model for calculation of business case**

Two models were designed, for the calculation of the total supply chain cost savings and for the calculation of CO\textsubscript{2} savings respectively. Both models can be used to calculate a business case for HSCC for commodities in general. The first is a mixed integer linear programming model implemented in software program AIMMS and the second model is a formula based on the logic of McKinnon and Piecyk [2011] using the output of the first model as input.

**Business case results for styrene monomer industry**

We applied the business model and optimization model to the European styrene monomer ("styrene") industry. Specific to this industry is the cluster of non-integrated Dutch styrene producers, causing the Netherlands to have a net capacity excess of about 1,800 ktons, whereas all other European countries apart from Spain have (major) net capacity shortages. Indeed styrene monomer flows from the Netherlands all over Europe [GTIS, 2013]. We focused on 4 Dutch industry players and built realistic profiles for them based on export data [GTIS, 2013], capacity data [CMAI, 2013] and data and industry knowledge available within SCE.
Figure 2: Impact of maximum customer parcel size on total savings

B.V. Sensitivity analyses challenged the assumptions underlying these profiles and showed results are quite robust (see below). We observed total supply chain costs may be reduced by 6% (€1,890,000) and CO₂ emissions by 11%, for 1,190 ktons of styrene shifted to 4C4Com by all participants in total. Yet, these savings have to be reduced with the coordination costs of 4C4Com. Investing in shared storage facilities for styrene is currently not profitable.

**Insights on business case**

Savings are caused by physically bundled volumes, better utilization of vehicle capacity and geographical swaps. If investing in shared storage facilities were profitable, this would cause additional savings by increasing the possibilities for bundling (including modality switches). Savings increase by collaborating in cases of high volumes and distance, large volumes shipped per tanker, high maximum parcel sizes of customers (i.e., the volume customers are willing to accept; see Figure 2), low maximum parcel sizes of producers (i.e., the volume producers are able to load due to physical or production restrictions), high reachability and high compatibility of end markets. Savings are robust for transport costs of vehicles other than tankers and the division of customer demand over participants, as long as each customer whose volume is shifted to 4C4Com is supplied by at least two participants.

We expect these insights to apply to commodities in general (i.e. not to styrene only). Commodities of which supply availability is spread over Europe should even lead to larger reductions in terms of HSSE exposure. Savings may increase up to a potential of €60 million for 10 commodities, while costs for including more commodities may only increase marginally.

**Recommendations to SCE B.V.**

- Do not implement HSCC for styrene only, but investigate possibilities to include more products (savings will increase correspondingly, costs may increase only marginally) and find potential ‘real’ participants
- Solve AIMMS optimization model for other products to verify whether the AsIs situation can be improved for those products
Rotterdam, June 27th 2013

This report is the result of my Master thesis project, which I conducted at Shell Chemicals Europe B.V. in Rotterdam. It is not only the end of my master Operations Management and Logistics at the University of Technology Eindhoven, but also the end of six fantastic years as a student. I have learnt incredibly much in many areas. Yet, what I will never forget, is how much fun and how many inspiring conversations I had with the great people I have gotten to know via the study association, my sorority and my study in general.

I would like to express my gratitude to a number of people for their role in this master thesis project. First of all, I would like to thank Jack Eggels for giving me the opportunity to conduct my research at Shell Chemicals. Jack, I am grateful that you have taken all this time to share your ideas and for continuously holding up a critical business mirror and inspiring me to think out of the box. Thanks for being not only a supervisor but also a great coach.

Secondly, I would like to thank my supervisor from the University of Technology Eindhoven, Jan Fransoo. Our discussions yielded a lot of new insights and helped me a lot, in particular in the time of developing the optimization model when I tended to get lost in complexity and you simply suggested to make the model less complex. At times our meetings were actually also quite funny. My thanks also go to my second supervisor, Zümül Atan. I would like to thank you for your help with the modelling, your intelligent remarks and positive support throughout.

From Shell Chemicals, I would like to thank all the people who provided input to this project. Special thanks go to Thomas Rieu, for being a guide, especially in the beginning of this project when I needed it most. Special thanks also go to Sheida Khajavi, for our brainstorm on the topic and for being such an inspiring and energetic woman. I should not forget Rik Onrust, Meritxell Martinez Aragon, Emil de Jong, Ton van Son, Edwin Kraan, Gerrie Grootveld, Jan van Berkel, Martijn Vermunt, Orson Slaats and Johann Grudelbach. Due to the nature of this project obtaining data was a challenge, but these people all helped me tackling it.

I would also like to thank the notable people I interviewed for my case studies. I would like to thank Kees Linse for sharing his thoughts on the Clearing House project and for providing clarity during the beginning of this project. Many thanks also go to Sven Verstreepen and Alex van Breedam from Tri-Vizor N.V., Michael Dörnemann and Alfred Kluitenberg from ARG and Michael Wisbrun, Murli Poonath and Michael Kimman from SkyTeam.

Thank you 4C4Chem participants for your input during project meetings. From the logistic service providers with whom Shell Chemicals collaborates and who have been so kind to make time for estimating costs with me, I would like to thank Henk van Dam of Interstream Barging B.V. and Joep Aerts and Gerrit Vis of Den Hartogh Logistics.

I would also like to thank my friends for their support during this project; I appreciated it a lot. Special thanks go to my parents, who are so dear to me and who are always there when I need them. And Jasper, what would I do without you? Thank you for your fancy tips and tricks on colour pallettes and GPS coordinates in R maps. But far more importantly, thanks for being so loving and patient and for starting your post-student life together with me.
Introduction

1.1 Problem statement

In this report we present the results of a master thesis relating to one of the three 4C4Chem research projects aimed at cross-chain collaboration in the chemical industry, initiated by the Dutch Institute for Advanced Logistics, Dinalog. This particular research project was carried out at Shell Chemicals Europe (SCE) B.V. in Rotterdam.

4C4Chem is driven by a desire to reduce transport flows in Europe, which have received considerable attention due to tight margins, environmental concerns, congestion and the foreseen reduced availability of long distance drivers over the next five years. About 10 per cent of these transport flows is caused by the chemical industry. Transport accounts for a large percentage of the total cost to serve some of the customers for those chemicals due to large distances, movements of relatively small volumes or inconvenient connections to preferred transport means.

There is a huge potential to be achieved through collaboration between producers, customers, suppliers and service providers to drive out waste and cost in the chemical industry [The European Petrochemical Association, 2007]. Horizontal supply chain collaboration (HSCC) in the commodity industry in particular, might have additional potential compared to ‘ordinary’ products since commodities are considered interchangeable. Hence, by collaborating horizontally these commodities might be combined, e.g. by allowing the pool to withdraw inventories from any (new) storage facility in the network, or bundled during transport, given certain new innovative rules. Horizontal cooperation in transport and logistics is active cooperation between two or more firms that operate on the same level of the supply chain and perform a comparable logistics function [Cruijssen and Salomon, 2004, p.12]. To improve the supply chain efficiency of the commodity business, Shell Chemicals is exploring opportunities for such a horizontal collaboration through a coordinating independent party. This leads to the following question:

What innovative business model for horizontal supply chain collaboration in the commodity industry can be developed that improves overall supply chain efficiency and what is the corresponding business case for a European explorative case study in the styrene monomer industry?

We leave all stages before and including production out of scope. To make the business model tangible and to be able to calculate the corresponding business case, we carried out a case study for a commodity produced by SCE B.V. fitting certain preliminary criteria for the concept to have potential: styrene monomer.

The rest of this chapter is organized as follows. To obtain insights into horizontal collaboration possibilities, a short literature review on relevant topics is presented in Section 1.2. Based on the general problem statement and results of the literature review, the research questions were formulated, presented in Section 1.3. The methodology used to answer these questions is discussed in Section 1.4. Shell Chemicals Europe B.V. is introduced in Section 1.5 and an outline of the remainder of this report finalizes this chapter.
CHAPTER 1. INTRODUCTION

1.2 Literature review

Apart from studying examples, models and benefits of HSCC, both in general industries and the chemical industry, we also review facility allocation literature, as the independent party might have the freedom to choose the production/storage facility the customer demand (i.e. that part for which the independent party is responsible) is supplied from. For a review on inventory pooling, a reduced safety stock effect caused by being able to withdraw inventory from a whole network rather than a single facility, we refer to Klawer [2012]. We finalize this section with relevant literature on business models, as the term is central in our project.

1.2.1 Examples of HSCC in general industries

In the field of transportation and to a lesser extent in the field of forecasting, as opposed to other areas such as procurement, inventory management and planning [Coppens, 2011], several case studies on HSCC have been published. In the area of transportation, combined shipments among shippers have been investigated by a.o. Strozniak [2003], Cruijssen and Salomon [2004], Krajewska, Laporte, Ropke, and Zaccour [2008], Odijk [2012] and Coppens [2012], varying from shipments of maritime containers and flowers to category drinks and any freight in general. They show the possibilities of useful increases in shipping frequency and service and higher capacity utilization, and that significant decreases might be gained in empty truck movements or truck kilometers and hence CO$_2$ emissions and transportation costs. Krajewska et al. [2008] and Cruijssen and Salomon [2004] looked at order combining settings by means of vehicle routing problems, for which the relevant background theory can be found in a.o. Ghiani et al. [2005].

In practice, quite some examples of combined shipments exist, including Tri-vizor (Section 2.2). Three others are mentioned here. Already in 1993, eight competing medium-sized Dutch producers of sweets and candy came to an agreement of intensive collaboration designed to increase the efficiency of their delivery processes to 250 drop off points in total [Cruijssen, 2004]. In 2007, the US-based Hanson Logistics completed the construction of its new multi-vendor consolidation center [Hanson Logistics, 2012]. Vendors benefit from improved lead times, control over transportation costs and shared truckload delivery. Another example relates to four fast moving consumer goods companies (HJ Heinz, FrieslandCampina, Hero Benelux and SCA) bundling their flows of goods by means of working together with LSP Nabuurs [EVMI, 2012].

Note that commodities require other types of bundling than general cargo as commodities are transported in bulk and can be co-mingled. Moreover, multiple modalities are used.

1.2.2 Examples of HSCC in the chemical industry

Though to our knowledge, no academic studies about the quantitative benefits of HSCC in the chemical industry have been published so far, practical examples do exist. The European Petrochemical Association (EPCA) Supply Chain Think Tank concluded in 2004 that the potential to drive out waste in the chemical industry through collaboration between producers, customers, suppliers and LSPs is huge [EPCA, 2007, p.9]. Several HSCC examples were mentioned:

Pernis Combi Terminal Created in 2005 in the Port of Rotterdam as a hub and spoke tri-modal solution combining road, rail and water services, initiated by Den Hartogh Logistics, Nijhof-Wassink, MCS (Multi-Modal Container Shipping) and VLS.

TAPP A.I.E. Started in 2006 between shippers BASF and Dow. BASF had owned a dock in the Port of Tarragona since 1998 for handling bulk chemicals. The incentive to collaborate arose when Dow started planning on installing a dock in the Port of Tarragona in 2003.
ComLog Created in 2003 as a common logistics procurement alliance between Bayer, Lanxess and Degussa. Located in the same Chemsite cluster (Ruhr area), they leverage the benefits of bundling demand for logistic services. This horizontal collaboration fostered vertical collaboration (which is logical according to Coppens [2012]): Comlog has a strategic partnership with Railion. Unfortunately, ComLog was unwilling to provide further data.

EPDC (European Pipeline Development Corp) Turned out to be unviable but started as a project to construct a propylene pipeline linking several producers and customers in northwest Europe, by example of ARG (see Section 2.3).

Other (more recent) examples have been identified by EPCA, in a working group together with strategy consultant A.T. Kearney and Cefic [The European Petrochemical Association, 2013]. This working group has identified phases for successful supply chain collaboration and five real life cases of vertical and horizontal collaboration in several industries. Unfortunately, at the time of writing this thesis, no further information can be shared about results.

A final example of horizontal collaborations in the chemical industry (apart from our case studies) concerns electronic marketplaces in the chemical industry, in particular Elemica. Elemica is an ERP system that could for example link the system of a customer of SCE B.V. to those of all their suppliers, provided they are also linked to Elemica. As such, Elemica supports only existing business relationships in the chemical industry [Christiaanse and Markus, 2003].

1.2.3 Allocation of demand to facilities

When transport inefficiencies are to be reduced, customers might be smartly assigned to storage facilities in the network in order to optimize distances and/or access to preferred transport means. The allocation of demand to facilities is usually based on minimizing (Euclidean) distances, lead times or costs between customers and facilities. Additional techniques may include customer clustering and balanced allocation. Allocation decisions have often been studied in combination with facility location decisions (for one firm only), which play a critical role in the strategic design of supply chain networks [Melo, Nickel, and da Gama, 2009]. Customer allocation has been based on mixed linear integer programming decomposition approaches [e.g. Dogan and Goetschalckx, 2007], genetic algorithms [e.g. Zhou et al., 2009 and Ho et al., 2012] and multiple ant colony approaches [e.g. Chan and Kumar, 2009).

1.2.4 Business Models

Both in practice and in literature diverse definitions of the extensively used term ‘business model’ exist. We propose to use the established definition of Osterwalder and Peigneur [2010]: “A business model describes the rationale of how an organization creates, delivers and captures value.” They believe a business model can best be described through nine building blocks that show the logic of how a company intends to make money and that are summarized in a business model canvas: customer segments, value propositions, channels, customer relationships, revenue streams, key resources, key activities, key partnerships and cost structure.

1.3 Research questions

Based on the problem statement and the literature review, research questions were defined.
1. What elements of the business models for HSCC identified in 4 case studies are options for translation to HSCC in the commodity industry?

Since other companies have already studied or actually applied cases of HSCC, we can learn lessons from these cases. In particular, we chose 4 case studies that together form a mix of chemical and non-chemical industries (as learnings might be valuable across industries):

- *The Clearing House*
- *Tri-Vizor*
- *ARG*
- *SkyTeam*

The Clearing House and ARG case study were selected because the interchangeable nature of a commodity is central to their concept. Tri-Vizor was chosen because it is an independent company with a different set-up (no shareholders) that already enables bundling transport between different companies, albeit between non-direct competitors (at least not between sellers of the ‘very same’ product). Commodities provide additional opportunities of HSCC versus ‘regular’ products because they can co-mingle. SkyTeam was chosen because it is one of the three largest airline alliances in the world. Under the SkyTeam umbrella, capacity is shared between airlines (codesharing) and as such an airplane seat might be viewed as a commodity.

For each case study we answer the following sub research questions:

1.1. What is the business model used by the coordinating party?
The company and its business model are shortly introduced, discussed in terms of information flows, financial flows and contracts and summarized in the Business Model Canvas.

1.2. What are key success factors for the concept to work?

1.3. What could be additions to the current business model that create value?

1.4. What are alternatives for the shippers to collaborate with the coordinating party?
This question aims at identifying mechanisms that strengthen the potential of the HSCC.

2. What business model can be designed for HSCC for commodities?

2.1 What is the business model used by the coordinating party?
The innovative business model is discussed in a similar way as in the case studies, including the advantages/value propositions. The case study learnings are used as as input.

2.2 What are key success factors for the business model to work?

2.3 What are the necessary steps to implement this business model?
We ask this question since the concept will not be ‘implementation-ready’ or barrier free.

3. What quantitative model(s) can be designed that support(s) calculating a business case for HSCC for commodities?
The model(s) should be able to calculate both supply chain cost savings and CO$_2$ emissions.

4. What is the business case corresponding to this business model applied to a specific commodity?
We select one or two commodities satisfying certain criteria, to validate the quantitative model and calculate a business case. Scenarios and sensitivity analyses provide additional insights. We will also evaluate the risk (HSSE exposure) involved.
CHAPTER 1. INTRODUCTION

1.4 Methodology

To answer the research questions, we follow a combination of the reflective cycle as defined by Van Aken et al. [2007] (see Figure 1.1) and the quantitative research model defined by Mitroff et al. [1974] [cf. Fransoo and Bertrand, 2002] (see Figure 1.2). Fransoo and Bertrand [2002] distinguish between axiomatic and empirical research. The latter sort fits the quantitative part of this research project best, as in empirical research the primary concern is having a model fit between observations and actions in reality on the one hand and the model developed for that reality on the other hand, rather than obtaining insights into the structure of the model itself.

The case class investigated in this project is chemical commodities. The case selected is styrene monomer, in particular produced by four industry participants as discussed in Chapter 5.

In the diagnosis phase of the problem defined in Section 1.1, four cases of HSCC are investigated by means of semi-structured interviews with people representing the corresponding firms/projects. The styrene industry is selected as an explorative case study and hence is also analyzed by means of public data, data available at SCE B.V. and semi-structured interviews with employees from the supply, land logistics, marine, strategy and commercial departments. We design both a business model and a quantitative model to calculate the business case. These models are designed for the set of problems (commodities). Thereby, we slightly deviate from the reflective cycle. The business case is case specific.

For the design of the quantitative model, we use the research model from Mitroff et al.:

1. Conceptualization
   - Literature review of bundling, facility allocation and inventory pooling models
   - Identification of variables that need to be included in the quantitative model

2. Modeling
   - Define causal relationships between variables and formulate a quantitative model
   - Build the model in a software program that can solve it given the necessary input
   - Validate the model for the 'no collaboration' situation with actual SCE B.V. data

3. Model Solving
   - Inventarisation of available, usable data at SCE B.V. and public data
     Ideally, it would be possible to gather supply and demand data from several European
commodity shippers. Apart from production capacities (not actual volumes) and total export volumes of countries though, this information is competitively sensitive. Hence, we cannot directly link producers to consumers, but the production capacities from derivatives of styrene, and hence consumers, are also publically available. Hence we develop realistic profiles for properties of possible participants, based on industry capacity data, export data and data/knowledge from SCE B.V..

- Application of model on real-life data / realistic profiles

4. Implementation

- Reflect on results obtained from the model and translate to insights, opportunities and next steps for SCE B.V. and the commodity industry in general

By having completed the stages above, we have also completed the regulative cycle.

1.5 Shell Chemicals Europe B.V.

Chemicals is one of the downstream businesses of Shell. Chemicals produces and sells petrochemical building blocks and polyolefins to industrial customers globally, varying from producers of detergents to plastic cups, from carpets to computers and from packaging to dashboards. Shell Chemicals Europe (SCE) B.V. is part of the Europe Africa group (i.e., besides America and Asia Pacific & the Middle East).

Shell entered the chemicals industry in 1929, via a Dutch partnership that manufactured ammonia from coke-oven gas. In the 1930s and ‘40s it also started production of chemical solvents from refinery gases and pioneered the production of butadiene and the manufacture of the first petroleum-based organic chemical in Stanlow (United Kingdom), liquid detergent.

In the decades that have followed, Shell chemicals has played a major part in the growth of the petrochemicals sector and corresponding technology. Shell Chemicals has around 850 staff in more than 30 countries, who work together with more than 2,500 business customers and 8,000 colleagues employed across Shell in chemicals-related roles, such as manufacturing or research. In 2012, Shell Chemicals sold 18,669 ktoms of chemical products and gained a revenue of $25 billion, of which 37 percent was the responsibility of the Europe Africa group. As such, it is one of the seven largest players in the chemical industry [Shell Chemicals, 2013; ICIS, 2012].

In Appendix A organisation charts are given for Shell Downstream, Shell Chemicals and Shell Operations & HSSE (Health, Safety, Security & Environment), zooming in respectively. The European Supply Chain unit is part of the latter unit.

1.6 Thesis outline

In this thesis first the case studies of existing HSCC business models are presented in Chapter 2. Based on learnings from these case studies, a general business model for the independent party, 4C4Com, is defined in Chapter 3. A general quantitative model that supports calculating a business case is formulated in Chapter 4. The case study of HSCC in the styrene monomer industry, including the business case results and insights, is described in Chapter 5. Chapter 6 finalizes this thesis by presenting conclusions and recommendations.
Two

Business Model Case Studies

In this chapter, the four case studies of horizontal supply chain collaboration (HSCC) selected in Section 1.3 are described. Relevant elements of the business model of the four related companies/projects are identified that can be translated to a new business model for a central independent party (4C4Com) responsible for the delivery of styrene monomer on a European basis.

For each case study, the business model is discussed via a general introduction and an elaboration on the collaboration in terms of information flows, financial flows and contracts. Also, we define key learnings for HSCC in the commodity industry (research question 1) finalizing each case study. The key success factors, alternatives for collaborating for shippers, possible additions to the current business model (sub research questions 1.1 - 1.3) and a representation in the business model canvas of Osterwalder and Peignier [2010] are discussed in Appendix B.

In the description of the business model, when the term ‘member’ or ‘participant’ is used, this means the company collaborates with the central party but not necessarily has a share in this central party. More general key success factors, that are common for all case studies and nearly all types of horizontal collaboration, including for 4C4Com, are identified in Chapter 3.

2.1 Clearing House

Main source: C. Linse (developer of CH project as former member of the management team at Montell, Basell and board member of Cefic)

2.1.1 Business model

The Clearing House concept was developed in 2006 in the Dutch ‘Chain Efficiency platform’ of SenterNovem, a governmental agency (now part of ‘Agentschap NL’) that initiated the project with the aim of reducing transport costs and impact on Health, Security, Safety & Environment (HSSE). 4 large European polyolefin producers (not including Shell) provided data to consultant Roland Berger in 2010 for the calculation of a business case based on real orders.

Polyolefins are commodities and produced and consumed all over Europe. Thus they constituted a good case for the Clearing House (CH) concept, which acknowledges that – once agreement has been reached on the specifications – commodities can be swapped, enabling producers to reduce transport kilometers by separating the physical delivery to customers from the contractual and financial flows. By using an independent entity, i.e. the CH, these swaps are not restricted to bilateral swap agreements, but can be optimized across multiple CH members. The CH determines from which facility inventory is withdrawn, irrespective of whether that facility is owned by the seller or a competitor.

The project has not been implemented in practice so far. According to Roland Berger the concept undoubtedly has potential but its success will depend on the readiness of the industry, since trust is a major issue in implementing such a fundamental change in industry operations.

The savings desired and anticipated on during the development of the concept mounted to €15 million, based on 30 percent savings in transport kilometers and a volume handled by the CH of 2100 kton, representing 10 percent of the total polyolefin production at the time. This
means that for all volumes above 160 kton, the savings were estimated to outweigh the costs of €1.2 million of the CH entity itself. However, Roland Berger came up with a different business case, based on a volume of 190 kton, that was *not* profitable in the ‘conservative’ base case. This must be due to different assumptions, but unfortunately these are not public information.

Since the project was stopped, a final business case for a CH concept ready for implementation and a clearer definition of the CH as an entity itself and its responsibilities (legal form, contracts between producers and CH, responsibility for off-spec material, location, tax, IT system etcetera) is still needed. Developers of the CH concept argued that the absolute commitment of producers is necessary given the scale of the collaboration and the abandonment of traditional ways of working, and that the legal form would have to be in accordance (e.g. by having participants have a share in the central entity). However, this is not strictly necessary, as we will see in the Tri-Vizor case in Section 2.2.

**INFORMATION FLOWS, FINANCIAL FLOWS AND CONTRACTS**

What is clear though, is that the CH was intended to be a ‘black box’ entity, either organized as a joint venture or a foundation. The intended collaboration concept is graphically shown in Figure 2.1. Participating producers (shippers) communicate a yearly forecasted volume to the CH. Based on geographical regions these volumes are *balanced* by the CH: a certain member delivers the same total volume for other members as they deliver vice versa. Communication of quarterly and monthly plannings of the declared sales (volume + location) and a matrix with transport costs enable the actual rerouting of orders via an optimization model.

![Figure 2.1: The concept of the Clearing House](image)

The CH holds all transport contracts to reduce insights into destinations of carriers and further support the ‘black box’ idea by minimizing links with member entities. As such, the CH is also an expeditor (a 3PL or even 4PL by truly directing the chain) and its responsibility in terms of insurances and liability goes much further (and is therefore more costly) than e.g. that of Tri-Vizor, as explained in Section 2.2. Shippers receive the invoice for transport costs incurred to meet their customer demands, including a surcharge for the services of the CH, via the CH. The CH also dispatches information to the participating producer from which the delivery is made. The shipper will not know which volume is delivered by which producer and
the producer does not know the destination of its withdrawn inventory. The shipper invoices the customer as usual. No money changes hands between members; all accounts are settled and managed by the CH. Since the CH enables structural industry (rather than opportunistic in case of bilateral swaps) optimization, it is important that end customers receive white label product ensuring it cannot be traced back to the actual producer, to prevent the CH from becoming an opportunity for members to increase market share.

The savings would be divided proportional to the volumes brought in by the participants, either by giving them a direct benefit via the CH charging them the actual (reduced!) transport tariff for supplying their original customers or by the CH charging them a fixed estimated transport tariff and post-remitting the discount. No mechanism is included that allows real-time comparison of the costs in the collaboration versus the no-collaboration situation, but these savings are implicitly guaranteed by the business case based on unattractive volumes from a transportation point of view.

2.1.2 Key learnings for HSCC in the commodity industry

Organisation Collaboration might be enabled via a neutral, ‘black-box’ entity like the Clearing house, with cont(r)acts as given in Figure 2.1, where the total savings (minus costs of CH services) eventually flow back to the producers. The operations performed by 4C4Com would naturally be different, but the division of responsibilities might not be. A decision would have to be taken on the additional responsibility over the intermediate storage, which is logically taken by the 4C4Com to optimize the entire supply chain.

No necessity of spread of supply over Europe To enable HSCC, producers should meet the criterium of not directly transforming the product into derivatives at the same or a close by location, since then bundling transport won’t yield any benefits. It is however not strictly necessary for HSCC that the producers, satisfying this criterium, satisfy a second criterium of being spread over Europe, as bundling and combining near end markets is still possible (see Chapter 3 and Chapter 5).

Possibility of producers being captive on a European scale In relation to the previous learning, though producers may be captive on a European scale (i.e. produce as much as they consume by transforming the commodity), this does not indicate an absence of possibilities for bundling, since bundling can take place not only for transport to customer locations of a company but also to its very own production locations elsewhere in Europe.

Delivery Though delivery (rather than pick-up by customers) in the CH concept is needed for reasons of not disclosing the origin of the product, delivery of the commodity made available to 4C4Com is also essential, albeit for another reason. In case of pick-up ownership of and hence authority over the product by the producers would end before bundling can take place. Hence, the volume needed to obtain sufficient savings will imply the percentage of customers that accept deliveries (rather than pick-up).

Number of participants The number of participants required to guarantee the success of multilateral swaps is higher than the number of participants required to enable HSCC in general, since multilateral swaps require a significant spread of producers over Europe. What remains vital is that the number of participants is at least such that individual volumes of the several companies to final destinations cannot be traced back. If aggregated volumes to final destinations are known to participants, this number theoretically equals 3 for bundling, but based on the judgement by anti-trust authorities, this number might be higher. However, if these volumes are not known, the minimum theoretical number seems to be 2. For as far as we can see now, these volumes are not known since bundling takes place where participants 'do not see it' (at a central location owned by the 4C4Com)
and moreover it might be flexible which demand is met by which supply, as long as total demand included matches total supply (that is, commodity picked up at a supplier might be used to supply that supplier’s demand and/or a competitor’s demand). However, again, based on the judgement by anti-trust authorities this number might turn out to be higher.

**Quality** Grades (i.e. product qualities) are of significant importance to at least part of all customers. Hence, it is key that – in case of physical co-mingling – the product grades are the same, which restricts the options for bundling.

**White label product not necessary per se** White labels may not be necessary since in case of the CH, customers infer the freight savings from the label when the product origins from a closer by supply location. If members are clustered rather than spread, ‘hiding’ the origin is not necessary if the customer accepts receiving a true commodity.

**Danger of customers eroding savings** The danger of customers eroding savings is still present due to inference of lower costs for producers.

**Spread in customers over Europe** Not only SCE’s customers should be spread over entire Europe, but the customers of competitors as well. Clearly defined assumptions in our case study will have to support the compatibility between (end) markets of participants.

### 2.2 Tri-Vizor N.V.

Main sources: A. van Breedam and S. Verstrepen (partners Tri-Vizor N.V.)

#### 2.2.1 Business model

Tri-Vizor was founded in 2008 as a spin-off of the University of Antwerp. As a neutral, independent party, it proactively designs and operates horizontal supply chain partnerships [Tri-Vizor, 2013] for 3 communities, based on a database of more than 100 shippers as of 2013, varying from companies in the Fast Moving Consumer Goods sector to pharmaceutical companies. Tri-Vizor enables ‘carpooling for cargo’, mostly for truck transport: it synchronizes supply chains of multiple shippers (usually but not necessarily part of the same sector) by consolidating transport flows in geography and time. As such, it allows a reduction in transport costs, carbon emissions, an increase in service levels and a reduction in inventory holding costs. (A shift to) Multi-modal transport is also possible when this helps achieving this goal based on sufficient critical volume.

**INFORMATION FLOWS, FINANCIAL FLOWS AND CONTRACTS**

The collaboration concept is graphically shown in Figure 2.2. Tri-Vizor acts as an orchestrator, based on a multilateral community contract with shippers (including contractual relations between shippers and between individual shippers and Tri-Vizor). The orchestrator is mandated to realize gains for the community by real-time bundling of flows on transport lanes that were evaluated as candidates for collaboration. For these lanes, all forecasts and orders are communicated to the orchestrator, unless significant differences in volumes and frequencies have been identified among shippers. The more in advance this communication and the more flexible the shippers, the higher the potential savings through smarter bundling. That is, Tri-Vizor actively identifies bundling possibilities and when a possibility implies a change in delivery date of one of the shippers, Tri-Vizor will ask the shipper whether this is possible, who in turn will check this with its customer(s). Hence, Tri-Vizor has indirect influence on due dates and frequencies.

The shippers remain the owners of contracts with carriers (e.g. Den Hartogh logistics) and each shipper in the community has a 1-on-1 contract with the same carrier. Yet it is
CHAPTER 2. BUSINESS MODEL CASE STUDIES

**Figure 2.2: The concept of Tri-Vizor N.V.**

the orchestrator who *contracts* the carrier on behalf of the shippers based on its mandate. By operating for a community, the carrier’s turnover will decrease but margins will increase (more) due to more efficient shipments. The carrier moreover obtains better stability in the long term.

The orchestrator is considered a neutral trustee for the community and a community manager. The orchestrator is also the paymaster: shippers pay the orchestrator for the transport costs ($TC$ over all shippers), a surplus ($f$) for the orchestrator activities and a percentage ($x$ over all shippers) of the community savings $\Delta$. The orchestrator pays the carrier $TC$ (though the shippers remain liable). Benefits of the paymaster concept for the shippers and Tri-Vizor of this paymaster concept are administrative (all savings are correctly calculated by the orchestrator and all activities are settled in one invoice; difference in payment terms is not significant), the carrier has no direct benefit or disadvantage since payment terms remain unchanged.

The way $TC$ and $x$ are divided over the shippers ($f$ is paid per shipper) is dependent on the negotiation phase; Tri-Vizor does not require a certain mechanism. From three parties on, the shippers might agree on the game-theoretical Shapley value but they might agree on another mechanism. An example with an agreement actually occurring in practice will clarify the payments given such an agreement:

2.2.2 Key learnings for HSCC in the commodity industry

**Organisation** 4C4Com might be a Joint Venture like the CH, but - depending on a comparison of the business cases and individual taste of the shippers - it might just as well be an independent, neutral, transparent and trusted party (a trustee) like Tri-Vizor with cont(r)acts as given in Figure 2.2, apart from the mandate rather than actual transport contracts with carriers. Making 4C4Com responsible for transport contracts will reduce the danger of disrupting the carrier market and support the ‘independence’ of the party:
enabled by appropriate contracts, destinations of carriers and total volumes per participant to those destinations can remain to be hidden for participants such that (sensitive) customer information is not implicitly shared. This is essential in particular when it is free which producer meets which demand. Since all the current ‘live’ communities TriviVizor orchestrates consist of indirect competitors (though two direct competitors in the FMCG industry are currently in the ‘rules of engagement’ phase under supervision of the European commission), applying the concept to communities between direct competitors, as in the case of commodities, will need some additional investigation and arrangements (e.g. with respect to anti-trust, quality and storage). Note that, on the highest level, the main differences with the CH concept are related to the legal entity and therefore also the division of savings and the ownership of transport contracts.

**Number of participants** See subsection 2.1.2.

**Compatibility** In accordance with several key learnings of the CH, compatibility in terms of end markets (if SCE B.V. is already supplying 90 percent of the demand in a certain region it will not make much sense for that region to collaborate), volumes, quality and delivery frequencies is essential; due to the restrictions in data availability within our case study assumptions with respect to these compatibilities must be well defined.

### 2.3 ARG

Main sources: M. Dörnemann (director ARG), A. Kluitenborig (dispatcher ARG)

#### 2.3.1 Business model

ARG mbH & Co. KG (formerly Aethylen-Rohrleitungs-Gesellschaft) hires out capacity for a 495 kilometre common carrier pipeline system, transporting about 1.7 million tons of ethylene a year between Antwerp and Gelsenkirchen in the Netherlands, Belgium and Germany [ARG mbH & Co, 2013]. Common carrier means that, within the available capacity, any customer of ARG – consumers, producers, companies that are both or third parties – can contract transport of ethylene at a standard product specification, general transport conditions and a public tariff system. Hence the ethylene molecules of several producers are physically mixed within the pipeline (co-mingled), which can be viewed as a form of HSCC. As such, ARG can be seen as a transport company that not only enables but also financially exploits this collaboration.

ARG is owned equally by shareholders BASF, INEOS, SABIC, SASOL and Westgas (Evonik). The physical pipeline grid is shown in Figure C.1 in Appendix C. It was built in 1970 for shareholders only to ‘help each other’ to solve short-term supply imbalances, who then were DSM, Veba, EC Erdölchemie, Bayer, BP and Hüls AG. The first three companies owned activities in ethylene and the latter three joined for strategic reasons. A key issue was the development of a common binding ethylene specification.

When many third parties wanted to join in a relatively short period of time, the system became a common carrier. Until the beginning of the 21st century, ARG mbh was managed by several staff members of the shareholders. Anti-trust regulation forced ARG to have independent staff. Around the same time, transport tariffs paid by the shareholders were set equal to the transport tariffs paid by other users and third parties, for the reason that trust among users is stimulated by equal treatment and trust is needed for a reliable pipeline system. The companies connected to the ARG grid are shown in Figure C.2 in Appendix C.
INFORMATION FLOWS, FINANCIAL FLOWS AND CONTRACTS

The collaboration is graphically shown in Figure 2.3. Each contract paid for by a transport principal is concluded between one supply point and one extraction point and accompanied by a transport planning. These plannings and the end-of-day balance are the basis for communication between ARG’s dispatchers and the third party control room, that operates the pipeline 24/7, contacts the control rooms of the connected companies and intervenes if necessary. ARG never owns the transported ethylene and hence is not responsible for off-spec material. Where the ownership changes hands from supplier to consumer depends on the contract agreed on.

![Figure 2.3: The concept of ARG mbh & Co](image_url)

The contracts can vary from spot to several longer terms. Currently, SCE B.V. has one long term contract with ARG due to corresponding large volumes; the other contracts are spot.

ARG’s pipeline transport tariff is comprised of a fixed basic rate and a variable distance-related rate, that is exactly the same for shareholders and other customers. The reason for the variable rate is unclear as physically ethylene does not flow from a supply to an extraction point. Discounts are offered based on timely conclusion of the contract, contract duration and projected transported amounts (for short distances adjusted rates apply). Amounts in excess or short of the contractual agreement can be offset against actual future transported amounts.

Customers can also use the ARG pipeline to either store or lend ethylene up to a certain amount and duration at a strongly reduced basic rate, if the technical status of the pipeline allows this. The depot and lend contract is currently rarely used by companies. The reason for this, as given by SCE B.V., is that companies will first try to conclude bilateral time swap agreements with other producers to offset contractual shortages/excesses with ARG.

Note that doing business with ARG requires some flexibility of all parties involved, as, while a certain supplier might have a disadvantage in one month, it will benefit in another. This flexibility also applies to ARG, since in the end the system needs to be in balance. A basis volume of 8 kton owned by ARG is always present to maintain this balance. ARG is responsible for buying/selling ethylene to solve end-of-month shortages/excesses with respect to this volume (due to limitations in the precision of gauges).

Only ARG knows what volumes flow in and out; the customers, including the shareholders, do not. The only information customers have consists of their contracts and what they can get
via bilateral communication with other firms. The additional information shareholders have is limited and aggregated. It consists of turnover, costs and end-of-month volume imbalances.

2.3.2 Key learnings for for HSCC in the commodity industry

Though ARG enables co-mingled transport of ethylene, the learnings on top of the Clearing House and Tri-Vizor case are limited due to the limited interface.

**Organisation** ARG is a transport company but moreover a common carrier system, explaining why only part of the customers of ARG are shareholders. As HSCC for commodities is intended to take place between a limited number of shippers, it is rather obvious all participating shippers obtain a (equal) share in the entity. Moreover, though ARG owns the pipeline, 4C4Com may not own the transport means as the reasons for outsourcing transport remain the same (many different modalities, volume discounts, flexibility etc.).

**Tariffs** The tariff system used by ARG is not aligned with real savings and used for participants varying in nature (shareholders and other customers). ARG’s goal is to maximize profit rather than to minimize costs for all participants. The tariff system used by 4C4Com will be for more homogeneous participants and therefore should be aligned with real savings. It could be similar to the CH or Tri-vizor set-up, depending on the legal entity choice.

**Liability and quality issues** Like ARG, 4C4Com needs to include rules for where the product changes ownership (incoterms). Moreover, responsibility for quality issues and short-term supply imbalances (e.g. SCE B.V. cannot supply its agreed volume) needs to be defined. Finally, the central entity needs to be actively involved in (on-going) agreement on the specifications of the product, especially in case of several grades. Gauges might have to be put in place everywhere where the commodity is co-mingled.

**Repositioning storage** Since transport of commodities over land and water cannot be compared to transport via one large storage tank (the pipeline), 4C4Com should have the possibility to invest in additional storage locations. Well-defined assumptions should support when and how much storage needs to be opened and what are strategic locations.

2.4 SkyTeam

Main sources: M. Wisbrun (managing director SkyTeam), M. Poonath (director of marketing and customer experience SkyTeam), M. Kimman (vice president IT SkyTeam)

This case study focuses on SkyTeam and a specific joint venture (JV) between members of SkyTeam, as a JV represents closer collaboration. This JV concerns the Trans-Atlantic collaboration between AirFrance-KLM, Delta and Alitalia. Because its business model canvas preserves the means between that of SkyTeam and an individual airline, and because none of the interviewees formally represents the JV, Appendix B only includes the canvas of SkyTeam.

2.4.1 Business Model

SkyTeam was founded as a co-operative (Dutch: coöperatie) in 2000, by airline companies Aeromexico, Air France, Delta Air Lines and Korean Air. Currently, SkyTeam has 19 members from all over the world. SkyTeam can be seen as an umbrella organisation, facilitating alliance partnerships between these 19 members, such that they can increase their networks, e.g. via codeshare agreements. Airlines moreover benefit from being a member of SkyTeam by gaining greater brand recognition over the world, easier reach to new destinations, enhancing the service they offer to customers, realizing cost savings and sharing best practices.
The focus for airlines in an alliance is to combine their networks to create expanded global networks, to align schedules and to share some marketing. Airlines participating in a JV are aligned more closely. They can agree on pricing and scheduling and possibly even market themselves as a single entity. JVs in the airline industry are said to have the benefits of a merger without nearly the same costs [Carlson Wagonlit Travel, 2012]. Concerning the Trans-Atlantic JV under the SkyTeam umbrella, Northwest (now Delta) and KLM were the first ever to sign a joint venture agreement in the airport industry in 1997. In 2010, the JV reached its current form. In French law, a JV is not a legal entity. The JV is allowed based on antitrust immunity (ATI), a specific ‘license’ in the airline industry that allows airlines to share information, costs and revenues because it benefits the final customer. That is, the airline industry provides infrastructure that is crucial to the world economy, but airlines cannot start global companies: foreign ownership is not accepted. However, market presence is crucial. This explains airline alliances (rather than takeovers) have the right to exist: to truly link networks. An alliance allows members to represent each other and hence to increase market presence.

**INFORMATION FLOWS, FINANCIAL FLOWS AND CONTRACTS**

The types of collaborations in the airline industry are graphically shown in Figure 2.4. The collaborations are explained in order of increasing intensity.

![Figure 2.4: Intensity of airline collaborations (the smaller the circle, the intenser)](image)

**INTERLINE AGREEMENTS**

Interline agreements and Global Distribution Systems (GDS) have existed since the early years of passenger transport. In interline agreements competing airlines accept each other’s tickets such that passengers only have to contact one airline to book their flights operated by many other airlines all over the world. The agreement does not allow for integration and efficiencies of more closer collaboration. It is concluded based on information available from a GDS (e.g. Amadeus), a central computer network that interconnects airline computer reservation systems and companies offering flight services (e.g. travel agencies, ticket websites). A GDS contains real-time information on seat availability and prices on flights from airlines all over the world. The agreement is always bilateral, resulting in a bill for the selling airline from the operating airline. The bills are multilaterally settled by a Clearing House for all affiliated airlines.

**SKYTEAM**

SkyTeam is basically nothing more than a project organisation (marketing wise an umbrella over all airlines). All assets and codesharing agreements remain in the hands of individual airlines or JVs. SkyTeam’s customers are the individual airlines. They have a contract with SkyTeam, paying contribution for the costs incurred to run the SkyTeam Office. The division of the contribution per member airline is mainly based on passenger kilometers.
SkyTeam creates value for its customers as explained above. Examples of projects via which members can enhance services to customers and realize cost savings are SkyPriority, SkyTransfer and SkyPort. SkyPriority offers consistent priority airport services throughout SkyTeam's network, allowing (final!) top customers to move through the airport in a faster way. SkyTransfer relates to the cooperation between SkyTeam members to improve the seamless travel experience of the customer, enabling e.g. straightforward transfer of luggage and passengers or defining policies for managing flight delays. SkyPort refers to airport co-location of members. Members realize significant synergies by optimizing the use of airport facilities such as check-in areas, ticketing areas, ground handling staff and equipment and lounge facilities.

The SkyTeam wide collaboration concerns projects improving operations and services. Cost and revenue information is only shared in JVs. E.g. in case of SkyPort, costs for implementing certain facilities (e.g. a shared lounge) are paid for by the airline/JV building and operating these facilities and other members pay a usage based fee. The projects are facilitated by SkyTeam. Hence, SkyTeam is not particularly sensitive for violating anti-trust laws.

JOINT VENTURE

The Trans-Atlantic JV between AirFrance-KLM, Delta and Alitalia is managed by a steering group and work groups (e.g. for network, marketing, IT, operations etc.), consisting of staff members of the individual airlines. After all, the JV is not a separate entity. Hence, it does not enter into contracts, hire employees, or have its own tax liabilities. These rights and obligations are handled through the partners directly and governed by contract law. The customers of the JV are passengers. The business model can be seen as an expansion of the business models of the individual airlines. The concept is represented in Figure 2.5.

Each airline brings in its capacity in the JV, mainly in terms of available seat kilometers (ASKs) and investments. The portfolios do not need to be of comparable size as this is usually not possible. The ATI allows the airlines to share all information relevant for the activities included in the JV (revenue, cost, schedule, capacity etcetera) and even to coordinate pricing. Any airline in the JV can sell seats on incorporated flights of any other operating airline in the JV; in essence it does not matter which airline sells a certain seat as 100% of the revenues are shared, yet the airline that can get the highest price naturally is the preferred seller. Only a part of all costs is shared. A lot of variable costs are proportional to seats and can be shared relatively easily, such as handling and fuel costs. Yet, certain assets remain in the hands of the individual airlines, such as the costs of airplanes. The reason is that the cost levels of the individual airlines are very different (w.r.t. efficiency of operations and proportions of e.g. owned versus leased and old versus new planes). The revenues and costs are shared among the airlines mainly proportional to brought in capacity, but the exact mechanism is not public.

Liability issues are rather complex and still a current topic. The JV is responsible from a customer perspective; agreements ensure e.g. lost luggage cases are properly handled. However, the JV is not a separate entity, so the individual airlines are the ones who are responsible in the end. E.g. in case of accidents the airline ‘owning the metal’ is liable.

In the end, the JV allows the airlines to offer passengers more affordable and higher quality tickets for a larger network, because the JV does not just offer a Trans-Atlantic network but includes the rest of the networks of the airlines, as represented by the dashed lines in Figure 2.5.

By collaborating, firstly the customer experience becomes more seamless and secondly, revenues are optimized multilaterally, rather than unilaterally in case of interline agreements.

Moreover, JVs easily allow for codesharing, an agreement between a flight operator and one or more other airlines to market and sell this flight as if they were operating it themselves (in practice viewed by multiple flight codes). This allows for increasing the number of flights to the same destination and hence provides flexiblity to the customer. Note that the largest
2.4.2 Key learnings for for HSCC in the commodity industry

Organisation Since bundling transport and opening new shared storage facilities requires extensive sharing of information, a JV in the airline industry is a closer resemblance to a suitable form for 4C4Com than SkyTeam. However, ATI is applicable in the airline industry only and partly allowed because there are so many airlines in the world. Moreover, the JV is not a separate legal entity, while this might not be applicable to 4C4Com as it will probably need to staff its own employees and conclude its own transport contracts. Also, in the JV all revenues brought in are shared, in order to optimize overall revenues. Since the shippers concerned in the 4C4Com concept largely serve the same market, this set-up might not be appropriate. However, sharing all costs for the volumes made available to 4C4Com will be necessary for a similar reason: to optimize overall costs.

Customer experience The main reason why the Trans-Atlantic JV was allowed in 1997 was because it would benefit the final customer. HSCC by means of individual structural shippers shifting volumes to 4C4Com might only be allowed by the European Commission when it is evident the final customer benefits.

Commodity A seat on a codeshared flight is not as true a commodity as a chemical commodity, because the rules of the operating airline apply (e.g. concerning maximum luggage allowance). This information must be disclosed to customers before they buy their tickets. Hence, the customer agreeing on a ‘codeshared’ flight or on a ‘codeshared’ (co-mingled) commodity, is essential. Yet, concerning liability, a seat on a codeshared flight is still a seat of the operating airline. A ton of a commodity in co-mingled transport no longer belongs to a certain producer and liability issues therefore require additional investigation.

Gain sharing In the Trans-Atlantic JV gains are largely shared proportional to available seat kilometers there (capacity of the commodity), rather than sold seat kilometers in order to optimize sales multilaterally rather than unilaterally. Financial flows related to incorporated tons of the commodity (‘seats’) might be largely shared proportional to costs made to supply original customers (sales of the commodity), because the sales remain in the hands of the individual producers.
Three

Business model 4C4Com

In this chapter, the general business model of the independent party in the horizontal supply chain collaboration (HSCC), 4C4Com, is defined, based on the learnings of the case studies and of commodity markets (in particular styrene monomer). The business model is introduced in Section 3.1. An elaboration on the collaboration in terms of information flows, financial flows and contracts can be found in Section 3.2. The key success factors are discussed in Section 3.3. A representation in the Business Model Canvas of Osterwalder and Peigner [2010] is given in Section 3.5. A discussion of the steps necessary to implement the 4C4Com concept finalizes this chapter. In the description of the business model, again the term ‘member’ or ‘participant’ is used for firms collaborating with 4C4Com, i.e. participating in the concept (so this does not necessarily imply shareholder).

A choice for the legal entity, including a definition of the kind of contracts between the shippers and 4C4Com (possibly multilateral), is left out of scope. We do provide some directions for the legal entity in Section 3.4. Moreover the number of participants needed, liability issues (e.g. in case of quality defects) and the division of costs and revenues are out of scope. If the business case for 4C4Com turns out to be positive, we have a proof of concept and additional investigation can provide an answer to those questions. Note that the key learnings of the individual case studies may provide some initial directions on these topics.

3.1 Introducing the 4C4Com concept

4C4Com is an independent entity enabling HSCC between structural shippers of commodities in Europe (like SCE B.V.). This does not include traders, who can be considered opportunistic rather than structural shippers. To be more precise, we define structural shippers to include:

- **Producers of commodities, that locally produce more than they consume** (but may be captive on a European scale).
- **Structural importers of commodities**. A certain company may e.g. be a producer in the Middle East and a consumer in Europe. Structural volumes imported by that company to Europe might also be suitable for collaboration.

4C4Com allows the structural shippers, who are both its customers and its partners at the same time (like in the Clearing House, Tri-Vizor and the SkyTeam concept), to simultaneously optimize logistic costs, service and health, safety, security and environment (HSSE). 4C4Com achieves this by optimizing the overall supply chain of the total volume that the participants make available to 4C4Com, i.e. 4C4Com optimizes across individual supply chains. The basic principle on which 4C4Com operates is to have the total supply made available to it meet the total corresponding demand handed over to it. This implies total demand of a consumer needs to be met, no matter by what shipper(s) this is physically supplied. It is precisely the unique nature of a commodity (i.e. the fact that it is not unique: it is interchangeable) that enables doing this. Hence, original sales (contractual and financial) relations between customer and shipper do not represent physical flows anymore. This concept includes the Clearing House concept (swap volumes geographically) but moreover includes the freedom to perform additional activities as it thereby can benefit a wider range of products (see subsection 3.3.1).
4C4Com can perform the following activities:

**Physically bundle flows** A physically bundled flow is defined as inventory being withdrawn from more than one supplier, either by allowing the product to co-mingle (e.g. on a bulk tanker), or by bundling separate parcels of suppliers (e.g. when bundling individual Rail Tank Cars (RTCs) originating from several suppliers’ locations on one train). This activity is performed by Tri-Vizor N.V. for truck transport.

**Swap volumes geographically** A geographical swap is already known in the chemical industry. In markets other than that of styrene, a central party like 4C4Com might also perform geographical swaps driven by distance savings (as explained in Section 2.1). When suppliers with excess net capacity are located close to each other, such as in the styrene market, currently there is no reason for a geographical swap (though there could be reasons for a time swap), since no transport costs will be saved (no distance savings). However, in the 4C4Com concept, since 4C4Com has authority over a large number of ‘common’ volumes (related to common end markets) rather than individual orders, reasons to perform such swaps do exist. Note that the geographical swaps are not one-on-one swaps (in terms of corresponding volumes) but rather collectively ensure that all supply meets all demand, as in the Clearing House concept. To illustrate this interpretation: rail transport ordered by 4C4Com may never consist of bundled RTCs of several suppliers; rather 4C4Com would have one ‘geographically’ bundled rail transport to a certain end market originate from one supplier and another ‘geographically’ bundled flow to another end market originate from another supplier due to relatively small volumes. Here, bundling takes place based on (final customer) destination. Yet transport by bulk tanker – given its high volume – might imply physically bundled transport, but even then the individual volumes withdrawn at the several suppliers do not have to be in accordance with corresponding individual demand volumes.

**Combine by opening a shared storage facility** Near end markets a shared storage tank could be opened. A shared storage facility can be beneficial because this implies larger volumes can be shipped per time, allowing for cheaper transport via cheaper modalities. Customers can then be supplied with co-mingled product from the storage location according to the (original) desired frequencies.

Moreover, once ‘life’, 4C4Com might aim at extending the concept by taking efforts to involve new members and to increase the scale or scope of existing activities in terms of volume (or regions) and number of products respectively.

### 3.2 Information flows, financial flows and contracts

The collaboration is graphically shown in Figure 3.1.

Participating shippers communicate a forecasted volume to 4C4Com for end markets for which agreement on collaboration exists (for the next and coming years). These end markets should be determined based on a pre-calculated (estimated) business case. Based on the forecasted volumes, 4C4Com strategically optimizes the network and decides which carriers to contract and from which supplier to withdraw which volumes (note that the pool of suppliers is the same as the pool of shippers but the shipper and the supplier do not have to coincide for a certain order). 4C4Com also decides whether, where and how much storage capacity to rent. Communication of quarterly and monthly plannings of the declared sales (volume + location) enable the actual fulfillment of customer orders, where 4C4Com has the freedom to physically bundle flows, swap volumes geographically and store product intermediately in the storage facilities it has opened.
Provided this is legally allowed, 4C4Com holds all transport contracts to reduce insights into destinations of carriers and further support the ‘black box’ idea by minimizing links with member entities, like in the Clearing House concept. As such, 4C4Com is an expeditor in the form of a 4PL (unlike Tri-Vizor). A 4PL directs the chain and often finds the best solution for the supply chain of its customer, not using own assets (like trucks) but counting on 3PLs and partners [Editors Logistiek.nl, 2007]. Hence, it owns and manages the transport contracts and performs the actual planning of transport. If the first is not allowed by the European Commission, one can think of a mandate set-up like used by Tri-Vizor. Shippers receive the invoice for transport costs incurred to meet their customer demands from 4C4Com, which should be determined according to some fair cost sharing mechanism. This mechanism is needed since the transport costs 4C4Com pays to carriers concern orders that are combined among several shippers and hence transport costs cannot be directly transferred. The invoice for transport costs should include a surcharge for the services performed by the 4C4Com, like in the Clearing House concept. Profit – if any (the profit lies more in the savings the shippers obtain by bringing in 4C4Com in the first place) – at the end of the year should again be divided according to some fair mechanism. 4C4Com pays the carriers for the bundled transport orders. 4C4Com also dispatches information to the participating supplier from which product is withdrawn to supply the combined demand of a customer / an intermediate storage location. The shipper will not know which volume is delivered by which supplier and the supplier does not know the destination of its withdrawn inventory. The shipper invoices the customer as usual.

3.3 Key success factors

This section describes the key success factors for the 4C4Com concept in terms of participant requirements and more general success factors.

3.3.1 Participant requirements

The shippers collaborating with 4C4Com should not only be a structural shipper, but moreover meet the requirements in this section. For an explicit translation to requirements a product has to meet in order to be suitable for HSCC, see Appendix D. Criterium 1 can be derived from all case studies. Moreover, criterium 3, 5 and 6 can be derived from the Clearing House learnings.
The Tri-Vizor case study was again inspiration for criterium 5 and additionally for criterium 4. Criterium 2 could be specifically derived from the ARG case study.

1. *The product is a true commodity and agreement exists on the specifications*
2. *Transport of the commodity is currently not mainly via pipeline*
3. *The total size of the shipments of the commodity is significant* *\[\text{\textsuperscript{*}}\]
   *The volume shifted to 4C4Com by all initial participants needs to be at least such that it makes up for the costs of operating 4C4Com, as will become evident from the business case. However, when more participants or commodities are included, smaller volumes might be sufficient to collaborate (given agreement on a fair cost sharing mechanism).*
4. *The supply chains of the collection of shippers are compatible in terms of end markets and delivery frequencies*
5. *Shippers experience high transport costs for a significant part of their customer orders*
   
   High transport costs may be due to for example large distances to customer's locations (i.e., there needs to be a spread of customers over Europe), inconvenient connections to preferred logistical means or transport of relatively low volumes.

It may also be desirable to optimize based on distance between source and destination (original interpretation of 'combine at the source', we now know this combining may also occur for other geographical swapping reasons), which may lead to significant savings as learnt from the CH project. Then, the collection of shippers moreover needs to meet the following requirement:

6. *Availability of the commodity is spread over Europe, either because it is stored in Europe (by a structural importer) or produced by a plant that locally produces more than it consumes.***

### 3.3.2 General succes factors

Palmer et al. [2012] investigated characteristics of collaborative business models and identified elements needed “to reach a sustainable and productive relationship” [p. 34], in interviews with 30 large companies from a variety of industries. If the business case turns out to be positive, these are also key factors that need to be assessed before actual implementation is possible.

**Essential elements** Without the following elements collaboration would not even get started:

*Trust* As stressed in all case study interviews, it is crucial that shippers trust both each other and 4C4Com. If an independent, neutral and transparent party like 4C4Com is absent, the community runs a severe risk of not efficiently working together in the long run. Lack of trust was the most important reason for stopping CH project.

*Transparency* If partners have access to collaboration-related information without loss, delay or distortion, transparency exists, while at the same time confidentiality of shipper specific data should be safeguarded.

*Solidarity* When facing difficult situations, problems should be solved as a team, e.g. in case of an unexpected supply shortage of a certain partner. Solidarity exists in case of a common expectation that value is attached to the relationship and that it is desirable to maintain it. This also requires a certain flexibility of participants.

*Mutuality* Partners should not get the feeling that it is always them who put in the highest effort to solve problems. Differences in efforts, costs and benefits with respect to a fair division should balance out in the long term.
Support Not mentioned by Palmer et al. [2012] but learnt from the case studies is that commitment from the highest levels of the participating organisations is necessary. This is because the 4C4Com concept implies going against traditional ways of working and hence will have quite an impact on their operations.

Improvement elements To make a collective of producers more efficient than the sum of the individual firms, the following elements need to be in place:

Organisational compatibility The business philosophies, objectives or corporate cultures should be well aligned among participants.

Operational symmetry and synergy See individual case studies. To reach synergies, flexibility might be needed, e.g. in case (minor) changes in delivery schemes (provided the customer agrees) provide considerable additional optimization opportunities.

Framework elements These elements define the legal structure and the scope of operations:

Contracts The collaboration should be supported and formalized by the correct legal documents in which the most important rules of engagement (including statements on the distributive element and quality, liability and anti-trust issues) are agreed on.

Type of collaboration The optimal type of collaboration, which can vary from type I to type III [Cruijssen and Salomon, 2004], is type III for the operations included in 4C4Com: the time horizon is not finite, for the volumes included in the collaboration operations are completely integrated. Three aspects are key here: 1) agreement on the legal entity of 4C4Com; 2) agreement on the volumes and corresponding operations included; 3) legal permission for this type of collaboration.

Distributive element

Gain sharing A well-structured cost sharing mechanism should be defined.

3.4 Remarks on legal entity

Though the definition of the legal entity of 4C4Com is out of scope, it is clear that 4C4Com should be an independent ‘black-box’ party like in the Clearing House concept, that is either a joint venture (JV), a foundation (as it is not necessarily aimed at making profit) or an existing 4PL. A JV is a formalized alliance between two or more organisations, where a new legal entity is created, the JV (e.g. a Dutch ‘B.V.’: a private company/Ltd.); the ownership of the JV is shared among partners; the identity of the participating organisations remains intact and the JV has its own management team [Duysters, van den Oord, and Post, 2004]. A 4PL is also a possibility as it has skills in directing the chain and finding the best solution for the customer by involving 3PLs and partners to carry out transport, storage, but often also planning and inventory management [Logistiek, 2007]. Yet, the nature of activities of a 4PL would go even further than usual given the nature of commodities.

The legal entity should be such that participants are treated equal, e.g. in a foundation they would all be members and in a JV they would all be shareholders, to enable optimization over the entire supply chain network and a fair gain sharing and to foster trust.

3.5 Business Model Canvas

Figure 3.2 shows the intended business model of 4C4Com in the Business Model Canvas. Apart from summarizing the sections above (i.e. in terms of value propositions, key activities, customer segments, revenue streams), it describes the key partners, cost structure, key resources, channels and customer (i.e. partner) relationships in more detail.
### Key Partners

| Producers | Members of the collaboration and at the same time also the most important customers |
| Logistc Service Providers | Both contractual and operational |
| Cloud software supplier | Planning software supplier |
| Legal advisors and accountants | |

*Motivations for Partnerships: Producers: enable value creation, LSPs: contractual partners as support for neutral ‘black box’ operations of 4C4Com (members no insights in destinations); outsourcing due to economies of scale and flexibility (core competence thinking); other: acquire knowledge*

### Key Resources

| People | Analytical, relation management skills |
| IT infrastructure | Strategic optimization tool, Operational optimization tool, Planning software, Cloud software, incl. member portal with appropriate links between actors’ IT systems |
| Proprietary knowledge | (Office) Not strictly necessary due to nature activities |

*IT infrastructure: Cloud software, incl. member portal with appropriate links between actors’ IT systems*

### Key Activities

| Optimizing transport flows by physical bundling of flows, bundling flows by geographical swaps and combining near end markets |
| Managing transport contracts and actual planning of transport |
| Managing stakeholders | Guidance of problem solving on (individual) demand and - if allowed - in regular joint meetings |
| Taking extension efforts | Involvement of new members and extension of existing activities in volume and number of products |

*Analytical, relation management skills: Strategic optimization tool, Operational optimization tool, Planning software, Cloud software, incl. member portal with appropriate links between actors’ IT systems*

### Value Propositions

| Allow customers to simultaneously optimize logistic costs, service and HSSE |
| The 4C4Com creates value by finding the lowest cost means to have the total supply made available to 4C4Com meet the total corresponding demand handed over to 4C4Com. As such, 4C4Com has the freedom to physically bundle flows, to swap volumes geographically and to combine in the Netherlands and near end markets by opening storage locations. It moreover creates value by CO2 savings through reduction of transport kilometers via environmentally unfriendly modalities, higher responsiveness (closer located to end markets) and increased lead time reliability. |

### Customer Relationships

| Community | • Online portal |
| • (Dedicated) personal assistance from 4C4Com |
| Face to face meetings with representatives of members, if possible with all members at the same time |
| Contracts | See figure 3.1 |

*Contracts: 4C4Com creates value by finding the lowest cost means to have the total supply made available to 4C4Com meet the total corresponding demand handed over to 4C4Com. As such, 4C4Com has the freedom to physically bundle flows, to swap volumes geographically and to combine in the Netherlands and near end markets by opening storage locations. It moreover creates value by CO2 savings through reduction of transport kilometers via environmentally unfriendly modalities, higher responsiveness (closer located to end markets) and increased lead time reliability.*

### Customer Segments

| Structural shippers of commodities | Only commodities are interchangeable. Only producers are stable suppliers of the commodity, however certain companies may be e.g. a producer in the Middle East and a consumer in Europe. Structural volumes imported by that company to Europe might also be incorporated in the ‘European’ collaboration. |
| The structural shippers moreover need to satisfy the following requirements: | • Agreement on specifications |
| • Current transport not mainly via pipeline |
| • (Initially) The total size of the shipments of the commodity is significant |
| • Compatible SC with other shippers in terms of end markets and delivery frequencies |
| • High transport costs for significant part orders (due to e.g. spread of customers over Europe) |

*If the shippers also want to combine at the source (out of scope for the styrene case study), the collection of shippers moreover needs to meet the following requirements: |
| • The available inventory of the product is spread over Europe |
| More types of commodities, sold by the members, might be incorporated in the 4C4Com concept.*

### Channels

| Member portal | In operation phase |
| Management team | Acquiring new members, negotiating contracts and expanding services in preparation phases and in operation phase |
| Front office | Direct contact regarding declared sales volumes, rerouting of deliveries in operation phase |

*80% of total transportation is executed by 4C4Com, 20% by third parties |

### Cost Structure

| Cost driven and value driven |
| FIXED COSTS: |
| Salaries (8 FTE: management team (2 FTE); front office (4 FTE); back office (2 FTE): €600,000) |
| Office rent and other (€200,000) |
| VARIABLE COSTS: |
| IT investments (€200,000) |
| Transport costs |
| During set-up: consultancy costs (€200,000) |
| IN CASE OF 4PL: part of these costs are spread over other activities and products |

### Revenue Streams

| Transport fees | Members are invoiced for the actual transport costs incurred to supply their original customer demand* |
| 4C4Com operation fees | A surcharge will be added to the transport fees for the costs incurred for 4C4Com services* |

*Corrected via appropriate gain sharing mechanisms to ensure fair allocation (out of scope)*

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**Figure 3.2: Business Model Canvas [Osterwalder and Peignier, 2010] of 4C4Com**
3.6 Necessary steps to implement 4C4Com Business Model

HSCC is only reachable if participants are willing to work in a continuous learning environment [Palmer et al., 2012]. First, the drivers of collaboration (savings in transport costs and CO₂ by physical bundling, geographical bundling and the possibility of investing in storage locations) and the barriers need to be established. The potential barriers of the 4C4Com concept, verified within SCE B.V. and listed according to decreasing priority, are:

- **Willingness of the industry** The largest barrier to implementing the 4C4Com concept is the willingness of the industry (note that exactly this issue was the show stopper of the Clearing House concept) due to the following aspects:
  - **Trust**
    Firms in the chemical industry are generally suspicious of their competitors. Trust is a crucial factor that would have to be established first.
  - **Derivation of competitively sensitive information due to too transparent operations**
    Firms in the chemical industry will be afraid that other firms will confiscate their customers due to the operations of 4C4Com being too transparent. A large number of participants may counteract this barrier.
  - **Logistics as a competitive advantage rather than a cost item only**
    Firms in the chemical industry might not be too attracted to the idea of helping other firms to reduce costs, despite also reducing their own costs.
  - **Customer acceptance**
    Customers will demand part of the savings of the new concept. Yet, when the ‘total cake’ is large enough, this will be less of a problem.

- **Agreement on HSSE standards**
  The requirements of SCE B.V. with respect to health, safety, security and the environment, in the areas of transport, storage and handling, are high when compared to industry averages. All participants would have to agree on the standards that apply to the flows included in the 4C4Com concept.

- **Agreement on quality specifications (grades) and responsibilities for off-spec material**
  All participants must agree on the specifications of the commodity (for styrene, this will not be a large problem) and on the responsibilities for (possibly co-mingled) material that does not meet specifications anymore, e.g. due to polymerization.

- **Fair cost and savings allocations**
  Since participants do not have to include the exact same volumes and physical flows do not represent sales relations anymore, participants need to agree on a gain sharing mechanism.

- **Legislative restrictions**
  Since the 4C4Com concept entails collaboration between large competing firms, the collaboration would have to follow certain rules in order for its existence to be legally allowed. Yet, when the concept can be proven to yield significant CO₂ savings and possibly reductions in HSSE exposure and when the industry agrees, the likelihood of this barrier being invincible decreases.

In the exploration phase [Palmer et al., 2012] these barriers should be open to discussion and solved together before continuing to the assimilation stage, in which preparation takes place for the upcoming changes by training staff and adapting current processes and information systems to the new ways of working in the actual exploitation phase. All stage dynamics should be subject to continuous learning.
Business Case Optimization Model

4.1 Model introduction

The goal of the quantitative model is to support calculating business cases of HSCC and running several scenarios such that we can obtain insights into parameters for which the savings are robust or sensitive respectively. The model is generic in the sense that it can be used to calculate savings from several kinds of HSCC, including combining at the source when producers are located far from each other (which is represented in corresponding transport costs).

We chose to model the problem as an optimization problem, for we believe it is the goal of both the individual participants (or it is at least a basis of fair comparison) and the independent party, 4C4Com, to determine a least-cost routing of certain commodities over a network of transportation services from their origins (production or storage location nodes) to their destinations (customer nodes, optionally via intermediate storage location nodes). Moreover, since the optimization horizon is strategic and hence we assume a mass balance of supply and demand, we assume demand and supply are deterministic. Therefore, we model the problem as a mixed integer linear programming problem.

The same model will be solved differently depending on the as-is or to-be situation.

As-is The model is solved once for each structural shipper. So per instance of solving the model, the set of shippers has only one element. The demand parameter at a certain customer node is equal to the demand to that shipper from that customer.

To-be The model is solved once (per scenario) for 4C4Com and if less than 100 percent of total demand is made available to the 4C4Com, in addition once for each producer. That is, there will be several scenarios of what volume is made available to the 4C4Com (centralized). Also, there will be several scenarios of whether and where to place storage (this is input rather than output). The volume that is left and has not been included in the 4C4Com concept still needs to be supplied by each producer on its own and can be seen as solving the as-is situation for a smaller demand volume per producer.

In this chapter this model is discussed in terms of sets, parameters, decision variables, scope, assumptions, model formulation and a corresponding explanation in subsection 4.2.1 - subsection 4.2.7 respectively. A separate model measuring CO$_2$ (savings) is discussed in Section 4.3, as the amount of CO$_2$ saved will be a result - not a goal in itself.

4.2 Total Supply Chain Costs Model

4.2.1 Sets

C Set of customers

P Set of structural shippers

S Set of intermediate storage nodes
CHAPTER 4. BUSINESS CASE OPTIMIZATION MODEL

K  Set of commodities

D  Set of physical bundling nodes; model technically, they cannot be existing producer nodes as the maximum volume that can leave from a production node is different than the maximum volume that can be loaded at that node, if volumes also arrive at that node

N  Set of nodes, \( N = S \cup P \cup C \cup D \), with \( i \in N \)

A  Set of arcs, with \((i, j) \in A\)

V  Set of vehicle types; vehicles are of a certain modality and a certain capacity

### 4.2.2 Parameters

\( d_{ik} \) Demand of a customer \( i \) for commodity \( k \), \( i \in C \)

\( o_{ik} \) Supply of a producer \( i \) for commodity \( k \), \( i \in P \)

\( t_{ik} \) Maximum volume (‘parcel size’) that can be loaded of commodity \( k \) at a supplier if \( i \in P \) and maximum volume of commodity \( k \) that can be unloaded at a customer if \( i \in C \)

\( \gamma_{ij}^v \) A binary parameter, equal to 1 if arc \((i, j)\) can be traversed per vehicle type \( v \), 0 otherwise; implies reachability of nodes

\( c^v \) Capacity of vehicle type \( v \)

\( \rho^v \) Utilization of vehicle \( v \)

\( f_{kv}^{ij} \) Fixed costs of transporting a certain commodity \( k \) over arc \((i, j)\) by vehicle type \( v \), including costs of loading/unloading/demurrage

\( c_{kv}^{ij} \) Variable costs of transporting one ton of a certain commodity \( k \) over arc \((i, j)\) by vehicle type \( v \), including costs of loading/unloading/demurrage

\( \alpha_{ik}^v \) Binary parameter equal to 1 if storage is opened for commodity \( k \) at node \( i \in S \), 0 otherwise

\( y_{ik}^v \) Storage capacity opened at node \( i \) for commodity \( k \), \( i \in S \)

\( i_{ik}^v \) Included (in costs \( f_{ik}^v \)) throughput at storage node \( i \), \( i \in S \), given storage opened at \( i \)

\( m_i \) Maximum throughput (based on maximum number of tankturns) at node \( i \), \( i \in S \)

\( f_i^k \) Fixed costs of opening storage for commodity \( k \) at node \( i \), \( i \in S \)

\( c_i^k \) Variable costs of opening storage per ton of the commodity \( k \) at node \( i \), \( i \in S \)

\( e_i^k \) Variable costs per ton of commodity \( k \) beyond the included throughput at node \( i \), \( i \in S \)

\( u^k \) Variable (manufacturing) costs of one ton of commodity \( k \) (i.e. value of commodity \( k \))

\( r \) Weighted average cost of capital

### 4.2.3 Decision variables

\( n_{ij}^{kv} \) Number of vehicles of type \( v \) carrying commodity \( k \) that traverse arc \((i, j)\)

\( x_{ij}^{kv} \) Total flow of commodity \( k \) over arc \((i, j)\) with vehicle type \( v \)

\( z_{ik}^v \) Excess throughput of commodity \( k \) at a storage node \( i \) beyond the included throughput
CHAPTER 4. BUSINESS CASE OPTIMIZATION MODEL

4.2.4 Scope

Inventory holding costs at the source, storage costs at the source and the effects of inventory pooling are not included. The introduction of these costs and corresponding effects requires incorporation of the time aspect, which increases analytical model complexity to an extent that only simulation is possible. Yet, insufficient reason seems to exist to develop such a model since total inventory holding costs as a percentage of total transport costs are 9% on average over all products of Shell Chemicals over 2011-2012 [Shell Chemicals 2011, Shell Chemicals 2012] and only 2.5% on average for styrene monomer. Hence, corresponding benefits are expected to be marginal. For more information on inventory pooling see Klawer [2012].

4.2.5 Assumptions

1. Demand and supply are deterministic

   The time horizon is strategic (total demand and supply are more or less stable) and the purpose of this study is to estimate a global business case; hence this assumption.

2. Delivery frequency and volume of customers is determined by their desirable parcel size

   The maximum parcel size customers receive dictates the delivery frequency and volume.

3. All volumes are delivered rather than picked-up

   Else transportation costs would not be incurred for those destinations and bundling would not be possible. The model assumes producers/4C4Com incur transport costs for each volume moving between two nodes.

4. Operations make sure the operational sequences of events and constraints of individual events are met

   Because we do not incorporate time, ensuring the mass balance is met is not sufficient, explaining the need for this assumption, which participants should be able to meet without too many problems. So when e.g. 10,000 tons are spread over 10 vehicles given a maximum parcel size of 1,000 tons, we assume operations ensure 1,000 tons is supplied to the customer per time the customer is visited (and not e.g. 4 times 2,000 tons and 6 times 333 tons). Note that the optimization model correctly takes this into account as formulas (e.g. for variable transport costs) are calculated over total volumes.

5. Costs of capital for inventory holding are incurred on half the storage capacity

   According to the sawtooth model, which seems to be sufficiently applicable because of equally spread deliveries, we can assume average inventory is half the storage capacity.

4.2.6 Model formulation

Minimize

\[
\sum_{k \in K} \sum_{v \in V} \sum_{i \in P \cup D \cup S} \left( n_{ij}^{kv} \cdot f_{ij}^{kv} + x_{ij}^{kv} \cdot c_{ij}^{kv} \right) + \sum_{k \in K} \sum_{i \in S} \left( \alpha_{ki}^{f} \cdot (f_{i}^{k} + \frac{1}{2} \cdot r \cdot u_{i}^{k} \cdot y_{i}^{k}) \right)
\]

\[+ \sum_{k \in K} \sum_{v \in V} \sum_{j \in S \cup C} \alpha_{j}^{k} \cdot x_{ij}^{kv} \cdot e_{j}^{k} + \sum_{k \in K} \sum_{i \in S} \alpha_{i}^{k} \cdot z_{i}^{k} \cdot e_{i}^{k} \]

Subject to

\[
\sum_{v \in V} \sum_{i \in P \cup D \cup S} x_{ij}^{kv} = d_{j}^{k} \quad \forall j \in C, \forall k \in K \tag{4.1}
\]

\[
\sum_{v \in V} \sum_{j \in S \cup C} x_{ij}^{kv} - \sum_{v \in V} \sum_{j \in P \cup D \cup S} x_{ji}^{kv} = 0 \quad \forall i \in S, \forall k \in K \tag{4.2}
\]
\[
\sum_{v \in V} \sum_{i \in D \cup S \cup C} x_{ij}^v = o_i^k \quad \forall i \in P, \forall k \in K \tag{4.3}
\]
\[
\sum_{v \in V} \sum_{j \in D} x_{ij}^v - \sum_{v \in V} \sum_{j \in S \cup C} x_{ij}^v = 0 \quad \forall i \in D, \forall k \in K \tag{4.4}
\]
\[
n_{ij}^k \cdot t_{ij}^k \geq x_{ij}^v \quad \forall i \in P \cup D \cup S, \forall j \in C, \forall v \in V : \gamma_{ij}^v = 1, \forall k \in K \tag{4.5}
\]
\[
n_{ij}^k \cdot t_i^k \geq x_{ij}^v \quad \forall i \in P, \forall j \in D \cup S \cup C, \forall v \in V : \gamma_{ij}^v = 1, \forall k \in K \tag{4.6}
\]
\[
n_{ij}^k \cdot y_j^k \geq x_{ij}^v \quad \forall i \in P \cup D \cup S, \forall j \in S, \forall v \in V : \gamma_{ij}^v = 1, \forall k \in K \tag{4.7}
\]
\[
n_{ij}^k \cdot y_i^k \geq x_{ij}^v \quad \forall i \in S, \forall j \in S \cup C, \forall v \in V : \gamma_{ij}^v = 1, \forall k \in K \tag{4.8}
\]
\[
n_{ij}^k \cdot c_i^v \cdot \gamma_{ij}^v \geq x_{ij}^v \quad \forall i \in P \cup D \cup S, \forall j \in D \cup S \cup C, \forall v \in V, \forall k \in K \tag{4.9}
\]
\[
\sum_{v \in V} \sum_{i \in P \cup D \cup S} x_{ij}^v \leq \alpha_j^k \cdot m_j^k \quad \forall j \in S, \forall k \in K \tag{4.10}
\]
\[
\sum_{v \in V} \sum_{i \in P \cup D \cup S} x_{ij}^v - t_j^k - z_j^k \leq 0 \quad \forall i \in S, \forall k \in K \tag{4.11}
\]
\[
x_{ij}^v, n_{ij}^v \geq 0 \quad \forall i \in P \cup D \cup S, \forall j \in D \cup S \cup C, \forall v \in V, \forall k \in K \tag{4.12}
\]
\[
z_i^k \geq 0 \quad \forall i \in S, \forall k \in K \tag{4.13}
\]
\[
z_i^k = 0 \quad \forall i \in S, \forall k \in K : \alpha_i^k = 0 \tag{4.14}
\]

4.2.7 Model formulation explanation

**Objective function** Total transport, inventory and storage costs need to be minimized. Note that the third term both has a variable storage cost part in it and a cost of capital.

(4.1) The total volume of a commodity arriving at a certain customer node \(i \in C\) must be equal to the demand of \(i\).

(4.2) The total volume of a commodity flowing out a certain storage node \(i \in S\) minus the total volume of a commodity flowing in that storage node must be equal to 0: there cannot be a net accumulation of product in a storage node.

(4.3) The total volume of a commodity flowing out at a certain producer node \(i \in P\) must be equal to the supply of that node.

(4.4) See explanation constraint (4.2).

(4.5) This constraint ensures flows per time to the customer do not exceed the maximum volume that can be unloaded at the customer: the customer is visited a sufficient number of times
to meet the maximum parcel size. That is, the total number of times a certain vehicle type \( v \) visits a customer \( j \) from a certain departure node \( i \) multiplied by the maximum volume a customer can handle needs to be larger than the total volume delivered to \( j \) by that vehicle type from departure node \( i \). Alternatively, a customer node \( j \) needs to be visited by a certain vehicle type at least as many times as the total flow delivered to it by that vehicle type divided by the maximum volume it can handle per time.

(4.6) This constraint ensures the producer is visited a sufficient number of times to meet the maximum volume that can be lifted at the producer. (See explanation constraint (4.5)).

(4.7) (and (4.8)) This constraint ensures the storage location is visited a sufficient number of times to meet the maximum volume that can be unloaded (loaded) at the storage location: the storage capacity. (See explanation constraint (4.5)).

(4.9) Only when a certain node \( j \) is reachable from a certain node \( j \) vehicle type \( v \), the flows from \( i \) to \( j \) via that vehicle can be positive. Otherwise, they are zero. Moreover, the total flow of a commodity \( k \) over arc \( (i, j) \) via a certain vehicle \( v \) cannot be larger than the number of times that vehicle traverses arc \( (i, j) \) multiplied by the vehicle capacity.

(4.10) This constraint ensures that when a node \( i \) is not reachable by vehicle type \( v \) from a certain node of departure \( j \), this vehicle type never traverses arc \( (i, j) \) (and hence \( n_{ij}^v = 0 \), which is more efficient than having only the objective function take care of this).

(4.11) If product is transported to a certain storage node, it needs to be ensured that storage capacity is available there (else there is no reason to visit a storage node). If no storage is opened, no product can be transported there. If not product can be transported there, it is also ensured no product can be transported from there by constraint (4.2).

(4.12) Because certain costs are only incurred for the excess throughput \( z_{kj} \), it is ensured this excess throughput is positive if the total flow to that storage node is higher than the minimum included throughput and zero otherwise (ensured by (4.14)).

(4.13) and (4.14) Nonnegativity constraints.

### 4.3 CO\(_2\) model

Not only do we want a model able to measure total supply chain costs, also we are interested in the reduction in CO\(_2\) emissions. We propose to use the simple and industry-wide acknowledged formula suggested by McKinnon and Piecyk [2011]:

\[
CO_2 = \text{tonnes transported} \times \text{average distance travelled} \times CO_2 \text{ emissions factor per tonne-km}
\]

where these emissions factors are given by McKinnon and Piecyk [2011] as well. Since bundling does not change the amount of tons transported between two nodes, nor the kilometers between these nodes, we propose to use the average number of vehicles used between these two nodes as a basis, assuming an average utilization of these vehicles and hence again the unit is tonnes transported x average distance travelled.

We then get for the total CO\(_2\) emission in grams for each individual run of the quantitative model (* denotes optimal value obtained from optimization model):

\[
CO_2 = \sum_{k \in K} \sum_{v \in V} \sum_{i \in P \cup D \cup S} \sum_{j \in D \cup S \cup C} n_{ij}^{kv} \cdot \ell_{ij}^{kv} \cdot c^v \cdot \rho^v
\]

where these emissions factors are given by McKinnon and Piecyk [2011] as well. Since bundling does not change the amount of tons transported between two nodes, nor the kilometers between these nodes, we propose to use the average number of vehicles used between these two nodes as a basis, assuming an average utilization of these vehicles and hence again the unit is tonnes transported x average distance travelled.
Five

Explorative case study

The European Styrene Monomer Industry

To explore the potential of HSCC in the commodity industry, including SCE B.V. as participant, an explorative case study was conducted. It concerns the movements of styrene monomer (hereafter called styrene) over Europe with Dutch supply as origin because the Netherlands have an extreme capacity excess compared to other European countries, that generally have a shortage. Styrene can be viewed as a case out of the case class commodities, for which the problem (Section 1.1) was defined.

Before discussing the business case results and the implications of the results in Section 5.5 and Section 5.6 respectively, we first describe why this specific case has been selected based on certain criteria in Section 5.1. The industry and the way the supply chain is currently organized at SCE B.V. is analyzed in Section 5.2. In Section 5.3 we shortly describe how we turned the general model formulated in Chapter 4 to an application for to the styrene monomer industry. Section 5.4 describes the approach of the business case.

5.1 Case selection

The product had to meet the 6 criteria as defined in Chapter 3. None of the criteria could be directly checked at shippers other than SCE B.V., but public data and industry knowledge supported checking them.

A list of products to choose from was formulated based on products being produced at least either in Moerdijk or in Pernis, the two Dutch production locations of SCE B.V. (for practical reasons). The evaluation of the criteria that supported the product selection is summarized in Table E.1 in Appendix E. This appendix includes an explanation of the translation of the criteria defined in Chapter 3 to measurable criteria. Based on that table, we will now continue explaining how we arrived at our conclusion to select styrene monomer for our case study.

Ethylene and propylene are primarily transported via pipeline and hence were excluded from further analysis. Based on the existence of many grades and small volumes within each grade, hydrocarbon solvents and caradol polyether polyols were also excluded. Butadiene, isoprene and dicyclopentadiene were excluded based on small volumes and low diversity in customer locations. Propylene oxide was excluded based on scale (in terms of both relatively low production volume and transport costs). MEG and ethylene oxide, though incurring high transport costs, were also excluded based on low production volumes.

Evaluation of the first three criteria thus left benzene and styrene as possible cases. Closer examination showed SCE B.V.’s benzene customers are located in the Netherlands, Belgium and Germany only. SCE B.V. produces benzene in the Netherlands and Germany. Thus benzene fails on criterium 5 and 6.

Hence, styrene monomer seemed the right candidate: it is a true commodity; currently not transported via pipeline; the total size of the shipments is significant; it is produced at several locations all over Europe and the high maximum transport cost score (see final column Table E.1) and the spread in customer locations all over Europe imply transport inefficiencies.
However, at closer examination, taking into account not only SCE B.V.’s customers but consumers all over Europe [CMAI, 2013], we noticed production and consumption often take place at the same company. That is, a lot of producers of styrene monomer are integrated and produce derivatives from styrene. See Appendix H for an overview of production and consumption capacities in Europe. These integrated producers will not support a concept of combination at the source: they have no inventory to exchange as they need it for producing derivatives. Hence, criterion 6 was reformulated to its current definition to include the property that local production is larger than local consumption.

5.1.1 No large potential at SCE B.V. for multilaterally reducing transport distances based on no product meeting criterion 6

This analysis yields an important intermediate result: with the current volumes of products produced by SCE B.V. and their market characteristics in terms of production and consumption, the motive for SCE B.V. to virtually combine inventories at the source in order to reduce transport distances is largely absent. No product in the current product portfolio seems to have sufficient potential to support this concept, or, in particular, to meet criterion 6.

5.1.2 Styrene monomer best fitting first five criteria

Yet, the analysis for styrene, suggesting the best fit with all criteria initially developed (criterion 4 to be verified in more detail later on, as explained in Appendix E) but implied a need for nuancing criterion 6, still suggested an opportunity to improve logistics across suppliers by HSCC as defined in Section 1.1, albeit in a slightly narrower setting than initially intended.

The fit with the 6th criterium can be refined: indeed styrene is produced all over Europe, but in a lot of cases it is produced to directly consume it. In fact, the Netherlands and Spain have a net capacity excess of about 1,950 ktons (see Appendix H) that has to meet the shortages in all other European countries. Hence, styrene can be assumed to flow all over Europe, which is indeed supported by SCE’s customer data [Shell Chemicals, 2011] and export data [CMAI, 2013] suggesting a total export of more than 1,900 ktons to European countries from the Netherlands and Spain (see Figure 5.1). At an average transport cost of \( \text{$/ton} \) [Shell Chemicals 2011, 2012] which for now is assumed to apply to other players in the industry as well, this means more than \( \text{million} \) of transport costs are incurred to move styrene over Europe.

![Figure 5.1: Export flows of styrene from the Netherlands and Spain within Europe](image)
5.2 Analysis of Styrene Monomer Industry

In this section we discuss the product, the market and the current supply chain at SCE B.V..

5.2.1 Product

Styrene monomer is an aromatic hydrocarbon. Under normal conditions it is a clear, colourless, flammable liquid. Styrene is easily stored and transported but will polymerize and hence potentially become dangerous unless properly handled. Therefore an inhibitor is normally added. Even so, in the marine shipping market it is classified as an ‘easy chemical’. It is one of the highest volume commodity chemicals traded.

Styrene is used to make polymers that are used in the manufacture of plastics and rubbers, including polystyrene (PS), expanded PS (EPS), styrene butadiene rubber (SBR) and unsaturated polyester resins. These products end up in e.g. food containers, cups or car interiors.

5.2.2 Market

The total styrene market consists of a volume of 5.75 million metric tons. Of this volume, around 2 million tons are available on the merchant market (defined as total styrene demand minus integrated demand minus contracted demand). The three largest players in the Netherlands on the merchant market are SCE B.V. and Ellba (50-50 Joint Venture Shell and BASF) in Moerdijk and LyondellBasell (LBI)/Bayer in Rotterdam (also a 50-50 Joint Venture). SCE B.V. produces both 500 ppm (i.e., 500 parts per million ethylbenzene) and 100 ppm styrene, which is of a higher quality and produced within Ellba. LBI also produces 100 ppm styrene.

The market shares of styrene monomer producers in Europe (based on capacity) are shown in Figure 5.2. The names and locations of producers and consumers of styrene all over Europe are shown in Appendix H. As shown in Figure 5.1 and explained in Section 5.1, the Netherlands and Spain have a net capacity excess and other European countries have net capacity shortages.

Since Europe is net short and the cost position of domestic styrene production is relatively high due to high ethylene prices, high domestic styrene prices make Europe a key target market for both Middle East and North American exporters. Current margins on styrene are thin or even negative. Styrene is often coproduced with propylene oxide (PO) (like at SCE B.V.) and PO margins are healthy. Hence PO currently drives production volumes. The West European styrene market is mature and supply and demand have steadily decreased over the past five years. The Central European styrene market is one which is heavily dependent upon imports, with only one domestic supplier. Styrene demand in Central Europe over the past five years has grown at a faster rate than GDP [CMAI, IHS Chemicals, 2012].

![Figure 5.2: Europe styrene producers, total capacity: 5,750 ktons [CMAI, 2013]](image-url)
5.2.3 Supply Chain at SCE B.V.

The supply chain is defined as the chain of processes that purchase raw materials, transform them into semi-finished and ultimately marketable products and distribute these to (end) customers. In Figure 5.3 an overview of the styrene supply chain at SCE B.V. is given.

![Figure 5.3: Supply chain styrene monomer](image)

We view each stage of the supply chain in this research project from a strategic rather than an operational level. Moreover, we don’t have the details on the supply chains of other participants. Still, to provide some background, a short explanation of each stage at SCE B.V. (production, inventory, demand, transport) can be found in Appendix F. In particular, we repeat the observations that are strategically relevant:

- **Production: styrene monomer is produced by SCE B.V. in Moerdijk only**
  Styrene monomer is produced in the MSPO1 plant (500 ppm, 100% Shell owned) and the MSPO2 (Ellba) plant (100 ppm, 50% Shell owned).

- **Inventory: Currently there are storage tanks (terminals) owned/rented by SCE B.V.**

- **Demand: % of all demand is fixed in contracts rather than available on the spot market**

- **Transport: % of SCE B.V.’s customers are pick-up customers**
  Currently SCE B.V. actually arranges the deliveries to % of its customers. Delivery is central to enable HSCC, but in essence whether SCE B.V. or its customers pay for the transport costs; in the end these transport costs are part of the total costs incurred for this product. We argue customers are rational and hence will be interested in the HSCC concept if SCE B.V. were able to offer lower costs (or even equal because of the effort involved on behalf of the customer to arrange the transport) than what the customer currently pays.

- **Transport: Current modality shares are given in Figure 5.4**
  Also note that all truck transport is in Full Truck Loads (FTL).
5.3 4C4Com Design Application

We applied the optimization model given in Chapter 4 to a HSCC concept in the styrene monomer market, for 4 participants as discussed in Section 5.4, by implementing the model in AIMMS, a software program designed for designing and solving large-scale optimization models. Simple parameters were directly inputted in AIMMS, extensive tables from the 'Commodity_Europe_Data.xls' file accompanying this project were read via the excel link of AIMMS.

5.4 Business Case Approach

In this section, we define the scope of the data included to calculate the business case. Since no direct data was available from firms in the styrene monomer industry other than SCE B.V., we had to make assumptions on data, discussed in the second part of this section. These assumptions are changed in sensitivity analyses later on. Finally, we define the scenarios we test (each resulting in a different business case).

5.4.1 Data scope

See Table 5.1 for a complete overview for the scope of the business case.

5.4.2 Basis assumptions

The most important assumptions (applying to all scenarios but one by one let go/replaced in sensitivity analyses) are listed below. A complete overview of the values of parameters and the elements of sets can be viewed in Appendix J.

1. Dutch export is caused by producers only

   According to Eurostat, Dutch export numbers relate to those flows truly originating from the Netherlands and ending in the reported export-to country. Styrene originating from other countries flowing via the Netherlands to its final destination is neither recorded as Dutch import nor as Dutch export. Hence we assume all Dutch export is caused by Dutch net production capacity.

2. Total supply (in scope) for the 4 participants equals supply given in Table 5.2.
Table 5.1: Data scope of business case calculation

<table>
<thead>
<tr>
<th>ASPECT</th>
<th>SCOPE</th>
<th>EXPLANATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region</td>
<td>Europe</td>
<td>Both the Netherlands and Spain are a net exporter of styrene monomer (see Section 5.1). All other European countries are net importers. Since the net capacity excess of Spain is small compared to that of the Netherlands, only the Netherlands was included.</td>
</tr>
<tr>
<td>Origin of flows</td>
<td>The Netherlands</td>
<td>Both the Netherlands and Spain are a net exporter of styrene monomer (see Section 5.1). All other European countries are net importers. Since the net capacity excess of Spain is small compared to that of the Netherlands, only the Netherlands was included.</td>
</tr>
<tr>
<td>Nature of participants</td>
<td>Net producers</td>
<td>Dutch export [GTIS, 2013] is the best available estimate of styrene flows leaving the Netherlands. According to Eurostat, Dutch export numbers relate to those flows truly originating from the Netherlands and ending in the reported export-to country. Styrene originating from other countries flowing via the Netherlands to its final destination is neither recorded as Dutch import nor as Dutch export. Hence (see assumption 1), we assume all Dutch export is caused by Dutch net production capacity. As explained in Chapter 3 structural importers may also be included but we do not have data on corresponding volumes.</td>
</tr>
<tr>
<td>Number of participants</td>
<td>4</td>
<td>There are 6 producers in the Netherlands with a net capacity excess: Shell (partly Ellba: 50-50 JV between Shell and BASF), BASF (completely Ellba), LBI (50-50 JV with Bayer), Bayer (50-50 JV with LBI), Styron and SABIC. Because the net capacity excess of SABIC is only small (see Appendix H) and so is that of Styron when taking into account Styron more or less completely supplies its location in Tessenderlo (Belgium) (which leaves nothing to bundle on that destination), that leaves us with 4 participants.</td>
</tr>
<tr>
<td>Names of participants</td>
<td>Shell, BASF, LBI, Bayer</td>
<td>Located resp. in Moerdijk and Rotterdam.</td>
</tr>
<tr>
<td>Number of destinations included</td>
<td>29</td>
<td>Taking into account only those countries receiving more than 1% of Dutch export and within those countries, only those consumers (for corresponding volumes see assumption 4, 5) that together account for 90% of the total export to these included countries (a criterium reached by requiring destinations to demand more than 10 ktons a year), 29 destinations are in scope (for names see Appendix H).</td>
</tr>
<tr>
<td>Total volume included</td>
<td>1,189,140 tons</td>
<td>This is the estimated volume flowing to the 29 destinations; 70 percent of the total average Dutch export over 2010-2012 [GTIS, 2013] (see Appendix H).</td>
</tr>
<tr>
<td>Modalities included</td>
<td>6</td>
<td>Truck, intermodal (rail), RTC, blocktrain, barge, tanker</td>
</tr>
</tbody>
</table>
Based on our scope we have 1,189,140 tons of styrene that originates from the 4 Dutch participants and flows to the 29 destinations. Given the lack of data per company, the 4 participants are assumed to be responsible for this export based on their net production capacities [CMAI, 2013] (see Table 5.2).

3. The model assumptions as explained in subsection 4.2.5 are met

4. Demand/consumer (city) to SCE B.V. equals demand given in Appendix H

Based on the customer profitability data of SCE B.V. 2012 [Shell Chemicals, 2012], export data [GTIS, 2013] and net capacity shortages of cities [CMAI, 2013] the demand per consumer for SCE B.V. was estimated. See Appendix G for the exact approach.

5. Demand/consumer (city) to BASF, LBI and Bayer equals demand given in Appendix H

Based on the export data [GTIS, 2013], the respective production capacities of BASF, LBI and Bayer in the Netherlands [CMAI, 2013] and net capacity shortages of cities [CMAI, 2013] the demand per consumer for each of these 3 participants was estimated. See Appendix G for the exact approach.

6. The maximum (or desirable) parcel size equals the maximum given in Appendix I

The maximum (or desirable) parcel size per customer equals 1 week of total production [Industry consultant Platts, 2013] unless known otherwise by SCE B.V.

7. No participant owns intermediate storage tanks in the AsIs situation and storage tanks can only be opened by 4C4Com for the volumes shipped via 4C4Com

8. The maximum parcel size per participant equals the maximum given in Appendix I

The maximum (or desirable) parcel size per participant is based on physical restrictions (e.g. depth of Hollands Diep) and production restrictions (parcel size should not be disruptive to production). In Moerdijk the physical restriction is known to be 6 ktons and in Rotterdam the production restriction is assumed to be 5 ktons.

9. All other parameters and sets needed for the business case calculations have values and elements as shown in Appendix J

All other parameters and sets needed for the business case calculations are based on (formulas fitted to) data available within SCE B.V. and data from LSPs with whom SCE B.V. collaborates. They truly represent the best estimate of parameters available rather than follow a certain rationale warranted by a lack of data as the assumptions listed above.

10. These parameters and sets, unless known otherwise, are the same/follow the same formulas as these assumed for SCE B.V.

Note that in reality other participants might incur higher/lower rates in some cases. Also 4C4Com might be able to negotiate lower rates, on which we will reflect later on.

<table>
<thead>
<tr>
<th>Producer</th>
<th>Net production capacity (KT)</th>
<th>Supply 100 &amp; 500 ppm styrene (KT)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCE B.V.</td>
<td>715</td>
<td>459</td>
<td>39%</td>
</tr>
<tr>
<td>BASF</td>
<td>275</td>
<td>210.24</td>
<td>18%</td>
</tr>
<tr>
<td>LBI</td>
<td>340</td>
<td>259.95</td>
<td>22%</td>
</tr>
<tr>
<td>Bayer</td>
<td>340</td>
<td>20%</td>
<td>22%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,670</strong></td>
<td><strong>1,189.14</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>
5.4.3 Scenarios

Several scenarios were used to calculate the business case, as some aspects are subject to further decision making (e.g. total volume or Regions included in the 4C4Com concept) and others to optimization (e.g. locations to place storage tanks).

Total demand made available to 4C4Com This implies the total volume that needs to be delivered to customers rather than picked-up. Shifting of demand occurs Region based rather than percentage based, since shifting a part of the demand to 4C4Com of one location may only further split up rather than optimize the overall supply chain. We define 6 Regions and 8 scenarios, as shown in Figure 5.5 and Table 5.3 respectively. Regions were based on geographical proximity. Region 2 in particular was based on future tanker bundling possibilities (furthermore no synergies between the destinations in region 2 can be expected and each country in the region can be seen as a separate subregion).

Storage locations and capacities Based on the analysis, we will define a shortlist of scenarios for the number of storage facilities, their locations and size.

Allocation of 100 grade demand Since styrene monomer has two grades, with 100 ppm being the best quality grade, customers that specifically demand 100 ppm styrene need to receive this grade. Customers being indifferent may receive both grades. Hence, we can view the part of the 100 ppm supply needed to fulfill all the 100 ppm demand as one commodity and the rest of the 100 ppm supply plus the total 500 ppm supply as another commodity. Allocation implies certain scenarios. We define 3 scenarios: all 100 ppm demand allocated to LBI and Bayer (1), all 100 ppm demand allocated to Shell and BASF (2) and all 100 ppm demand allocated to all 4 participants (3). Allocation within a scenario is based on production capacity. Note that BASF, LBI and Bayer all produce 100 ppm styrene and SCE B.V. produces both (Ellba produces 100 ppm).

![Figure 5.5: Regions of demand for styrene monomer in Europe](image-url)
Table 5.3: Region based volume shifted to 4C4Com

<table>
<thead>
<tr>
<th>AsIs Regions</th>
<th>ToBe 4C4Com Region</th>
<th>ToBe Location</th>
<th>4C4Com Volume shifted to 4C4Com (tons)</th>
<th>% of volume in scope</th>
<th>Volume B.V. shifted (% of scope (prod. capacity 715 ktons))</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>—</td>
<td></td>
<td>0</td>
<td>0%</td>
<td>0% 0%</td>
</tr>
<tr>
<td>2,3,4,5,6</td>
<td>1 Norway, Sweden, Finland</td>
<td></td>
<td>190,690</td>
<td>16%</td>
<td>9%</td>
</tr>
<tr>
<td>1,3,4,5,6</td>
<td>2 Turkey, Italy, Bassens (France)</td>
<td></td>
<td>47,800</td>
<td>4%</td>
<td>4%</td>
</tr>
<tr>
<td>1,2,4,5,6</td>
<td>3 Czech Republic, Austria, Poland</td>
<td></td>
<td>171,110</td>
<td>14%</td>
<td>4%</td>
</tr>
<tr>
<td>1,2,3,5,6</td>
<td>4 Germany, Carling (France)</td>
<td></td>
<td>352,200</td>
<td>30%</td>
<td>15%</td>
</tr>
<tr>
<td>1,2,3,4,6</td>
<td>5 Belgium, Wingles (France), Ribecourt (France)</td>
<td></td>
<td>398,710</td>
<td>34%</td>
<td>31%</td>
</tr>
<tr>
<td>1,2,3,4,5</td>
<td>6 United Kingdom</td>
<td></td>
<td>28,610</td>
<td>2%</td>
<td>1%</td>
</tr>
<tr>
<td>— All</td>
<td>All 29 locations</td>
<td></td>
<td>1,189,140</td>
<td>100%</td>
<td>64%</td>
</tr>
</tbody>
</table>

5.5 Business Case Results

In this section, we define the results of the business case calculations. A verification of the AsIs situation and a comparison of the AsIs versus the several ToBe situations is discussed firstly. More importantly, the mechanisms behind the savings, the drivers of the savings, including insights of sensitivity analyses; the aspects for which the savings are robust (rather than sensitive as for the drivers), again including insights of sensitivity analyses and the drivers of the attractiveness to place storage are also explained. Finally, we evaluate the translation of the savings derived from the optimization model to potential real savings in operations.

Note that generally, the flows of an entire network (i.e., that of 4 participants) are discussed, rather than those of SCE B.V. only. Secondly, note that when we state ‘100% ToBe 4C4Com’, we mean the entire volume in scope (1,189,140 tons) is shifted to 4C4Com. Yet, for SCE B.V., this implies only 64% of its total production capacity (715 ktons) is included.

5.5.1 Verification and validation of the AsIs situation

Verification is the process of determining that a model implementation accurately represents the conceptual description of the model and the solution to the model. Validation is the process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model [Thacker et al., 2004, p.2].

The model and its results are verified and validated in the following ways:

- **Verification step 1**: Identify and remove errors in the model
- **Verification step 2**: Determine logic of results
- **Validation step 1**: For those styrene consumers with whom Shell currently collaborates, compare true modalities on corresponding lanes with model modalities
- **Validation step 2**: Compare average transport costs per ton currently incurred by Shell with average transport costs per ton derived from the model
CHAPTER 5. EXPLORATIVE CASE STUDY
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For the verification and validation, including enlighting examples, the reader is referred to Appendix K. We can conclude the optimization model performs correctly and seems to sufficiently represent the true 'strategic' optimization of supply chains. It is also explained in Appendix K why we expect the savings to apply to an operational setting in a similar way.

5.5.2 AsIs versus ToBe

ASIS VERSUS SHIFTING ALL REGIONS TO 4C\textsubscript{4}COM

As expected, the 4C\textsubscript{4}Com concept yields savings in terms of transport costs and CO\textsubscript{2} emissions.

Concerning the scenarios calculated, we did not include results on scenarios in which 100ppm supply was allocated to 2 out of 4 suppliers. We only included the scenario in which the 100ppm demand was supplied by all 4 suppliers, as this scenario both performed the best on average (average differences in total supply chain costs were equal to a mere 0.2%) and makes more sense from an industry perspective. The better performance is due to 4C\textsubscript{4}Com being able to truly optimize from which location to source 100 ppm styrene, which might be Rotterdam in one case and Moerdijk in another. Moreover, we did not include results on scenarios in which storage tanks were placed in optional storage locations, because this did not lead to a decrease in total supply chain costs for any optional storage location.

The total supply chain costs and CO\textsubscript{2} emissions are given for the AsIs situation and the situation in which 100 percent of the demand is shifted to 4C\textsubscript{4}Com (i.e., all 5 regions) in Table 5.4. Savings are given in Table 5.5.

Based on the results mentioned above, the most important direct observations for the styrene case study in Europe are listed below. See the next sections for an elaborate explanation.

• Investing in storage tanks is neither profitable in the AsIs situation nor when collaborating horizontally.
• Total supply chain cost savings when shifting all demand to 4C\textsubscript{4}Com are €1.9 million/year (6%/year); to be decreased with operating costs of 4C\textsubscript{4}Com/year.
• Total savings in CO\textsubscript{2} emissions when shifting all demand to 4C\textsubscript{4}Com are 11%.

The volumes transported on lanes between \((i,j)\) pairs (i.e. Origin-Destination (OD) pairs) and the corresponding number of vehicles, both in the AsIs situation and the ToBe situation, are given in Appendix L. Maps representing those flows, in Figure 5.6 to Figure 5.8 respectively, show the size, modality and destination of flows.

SHIFTING DEMAND TO 4C\textsubscript{4}COM PER REGION

Concerning Regions 1 to 6, we also investigated shifting only one Region to 4C\textsubscript{4}Com respectively. The volumes transported on lanes between \((i,j)\) pairs (i.e. Origin-Destination (OD) pairs) and the corresponding number of vehicles for those regions, are given in Appendix L. The total supply chain costs and CO\textsubscript{2} emissions are given in Appendix M. Two relevant observations:

• Region 1 (Norway, Sweden, Finland) and Region 4 (Germany, Carling (France)) are most appropriate for collaboration (drivers are explained in next sections).
• Total supply chain cost savings when shifting all regions to 4C\textsubscript{4}Com are higher than the sum of the individual supply chain cost savings per region, which is due to 4C\textsubscript{4}Com having more freedom to optimize the overall chain.
Table 5.4: Total Supply Chain costs and CO$_2$ emissions [based on McKinnon and Piecyk 2011] for AsIs and 100% ToBe 4C4Com

<table>
<thead>
<tr>
<th>Situation</th>
<th>Shipper</th>
<th>Total Supply Chain Costs</th>
<th>kg CO$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AsIs</td>
<td>Shipper 1</td>
<td>€10,295,000</td>
<td>10,012,000</td>
</tr>
<tr>
<td></td>
<td>Shipper 2</td>
<td>€6,119,000</td>
<td>5,859,000</td>
</tr>
<tr>
<td></td>
<td>Shipper 3</td>
<td>€7,246,000</td>
<td>6,841,000</td>
</tr>
<tr>
<td></td>
<td>Shipper 4</td>
<td>€7,246,000</td>
<td>6,841,000</td>
</tr>
<tr>
<td></td>
<td>Shipper 5</td>
<td>€0</td>
<td>0</td>
</tr>
<tr>
<td>Total all shippers</td>
<td></td>
<td>€30,905,000</td>
<td>29,554,000</td>
</tr>
</tbody>
</table>

100% ToBe 4C4Com

| Shipper 1       | €29,015,000 | 26,166,000 |
| Shipper 2       |             |            |
| Shipper 3       |             |            |
| Shipper 4       |             |            |
| Shipper 5       |             |            |
| Total all shippers |         | €29,015,000 | 26,166,000 |

Best ToBe: all Regions included in 4C4Com concept.

Table 5.5: Cost and CO$_2$ [based on McKinnon and Piecyk 2011] savings between the AsIs and the 100% ToBe 4C4Com situation

<table>
<thead>
<tr>
<th>Total SC savings AsIs - 100% ToBe 4C4Com</th>
<th>Total CO2 savings AsIs - 100% ToBe 4C4Com</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute €1,890,000</td>
<td>3,388,000 kg (emission of 120 households during 1 year$^1$)</td>
</tr>
<tr>
<td>Relative 6%</td>
<td>11%</td>
</tr>
</tbody>
</table>

Best ToBe: all Regions included in 4C4Com concept. $^1$Source: Hoornweg et al. [2011].

**HEALTH, SAFETY, SECURITY AND ENVIRONMENT**

By collaborating via 4C4Com, the risk or HSSE exposure decreases. Styrene is a black banded product (high risk) due to possible polymerization. Though handling may increase by physical bundling, less transport flows are needed in total (see general decrease in number of vehicles in Table 5.6) and hence total HSSE exposure decreases. Because the countries of origin and countries of destination do not change by collaborating and shifts in modalities are minor for this case study, the Risk Exposure Index (REI) tool of SCE B.V., that is independent of total volume transported per time, cannot measure a delta. Yet, for other products, where supply is available for sharing spread over Europe, significant decreases in risk will be measurable.

5.5.3 Mechanisms behind savings

We can identify three mechanisms behind the savings in total supply chain costs and CO$_2$ emissions in this case study. Generally more than one mechanism applies to one lane. More mechanisms exist when investing in storage tanks is profitable (e.g. significant modality shifts).

**Physical bundling** HSCC via the 4C4Com concept allows for physical bundling, enabled when the parcel size customers can take is higher than the parcel size individual producers can supply due to physical or production restrictions. Table L.4 – by the flows to and from the dummy location (“du1”) created to enable physical bundling – shows that styrene from both producer 3 and producer 4 is physically loaded on the same tanker (i.e. boat). Thus,
the tankers transport a higher volume than they would have transported for an individual producer and hence against lower variable transport costs (also less tankers are needed as can be seen in Table 5.6 and hence less fixed costs are incurred, though this is due to a combination of physical and geographical bundling). In this case study physical bundling is only used for tankers. RTCs could be bundled in Kijfhoek in an operational setting (as expected this does not make sense in a strategic optimization setting). Physical (rather than geographical) bundling on barges does not make sense from a cost perspective.

**Better utilization of the capacity of vehicles** A larger volume allows for a smarter division over vehicles and hence leaves less 'rest' volume. E.g. to customer 3 we observe 50 barges and 32 trucks in the AsIs, while in the ToBe 50 barges and 19 trucks are sufficient. Note that this behaviour explains the large reduction in the number of trucks in Table 5.6.

**Geographical swapping** Since 4C4Com has the freedom to source product from any producer, as long as total included supply meets total included demand, there is no reason to stick to the original flows. We identify two submechanisms of geographical swaps:

**Location** Though possibly surprising given the short distance, the differences in location between the producers in Moerdijk and Rotterdam (Maasvlakte), which are related not only to distance (80 kilometers via road) but also to port charges (e.g. a tanker from Moerdijk and ease of access/distance via barge (e.g. a barge from Moerdijk), cause Rotterdam to be the favourable source for some lanes and Moerdijk for others.

**Bundling** When the maximum parcel size of customers is higher than the parcel size individual producers can supply, bundled volumes can be transported on one vehicle (or even allow for a shift in modality). As should be clear now, bundling does not need to occur physically but may also occur geographically, that is 1 or 2 rather than all 4 producers may supply an entire destination. To mention two out of many examples (see Table L.4): in the 4C4Com concept customer 2 is entirely supplied by producer 1 and customer 15 by both producer 1 and producer 2. Just like physical bundling, geographical bundling not only allows for a higher volume to be transported on the same vehicle but also for a reduction in the number of vehicles. Taking barges as an example, we see a shift from barges transporting between 1,150 and 2,000 tons to barges transporting up to 3,000 tons due to geographical bundling. In a sense one can also call this a modality shift; in any case economies of scale drive savings.

Both physical and geographical bundling yield a higher capacity utilization of vehicles, reducing not only variable costs (in case of tankers) but also the number of vehicles needed (see Table 5.6). The differences between the “zoomed in” maps in Figure 5.7 and 5.8 with flows between OD pairs confirm the mechanisms: one can observe less and ‘thicker’ flows (a scientific spot the differences game?). See Figure 5.6 for a complete overview of the AsIs situation.

**Table 5.6: Change in number of vehicles in AsIs and 100% ToBe 4C4Com situation**

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Change in nr of vehicles (%)</th>
<th>Change in nr of vehicles (abs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck</td>
<td>-7%</td>
<td>-201</td>
</tr>
<tr>
<td>RTC</td>
<td>-10%</td>
<td>-35</td>
</tr>
<tr>
<td>Blocktrain</td>
<td>-4%</td>
<td>-9</td>
</tr>
<tr>
<td>Barge up to 1150, 1500, 2000, 3000 tons</td>
<td>-6%, -82%, -4%, 86%</td>
<td>-15, -9, -2, 12</td>
</tr>
<tr>
<td>Tanker up to 6000 tons</td>
<td>-15%</td>
<td>-18</td>
</tr>
<tr>
<td>IMrail</td>
<td>1%</td>
<td>58</td>
</tr>
</tbody>
</table>
Figure 5.6: Styrene monomer flows in Europe in the AsIs situation
Figure 5.7: Zooming in on the AsIs situation depicted in Figure 5.6

Figure 5.8: Zooming in on styrene monomer flows in Europe if 100% 4C4Com
5.5.4 Drivers of savings

The drivers of the savings in total supply chain costs and CO₂ are not only interesting from a scientific perspective, to obtain a better understanding of the potential of HSCC for commodities, but also from a business perspective, for the same reason and moreover since the initial parameter setting is part of an explorative rather than an ‘actual’ case study. Sensitivity analyses and analyses per region/individual destination yielded these drivers.

Higher volume and distance To obtain insights into what supply chains are the most attractive to shift to 4C4Com, we studied the effect of volume and distance on total supply chain cost savings. Volume and distance intuitively cannot be viewed in isolation, as confirmed by the results. For example, a volume in the same order of magnitude (350 - 400 ktons), i.e. to Region 4 and Region 5, yields 2.7 times as many cost savings for Region 4 as for Region 5, since the average distance to destinations in Region 4 is (fortuitously exactly) also 2.7 times as high. A similar explanation applies to Region 1 and Region 3 respectively, yet average savings are 8 times as high versus a twice as high distance, since other drivers also play a role (e.g. maximum parcel sizes, fixed costs of tanker transport).

A more detailed analysis in Figure 5.9 also shows that the low distance, low volume destinations generally do not yield considerable savings, while higher combinations (either for volume or distance or both) do. A separate graph is shown in Figure 5.10 for destinations reachable by tankers with low variable transport cost versus fixed costs (ratio at least twice as low as for destinations in other graph), i.e. for which increasing parcel sizes has more impact.

Figure 5.9: Impact of distance and volume on absolute savings from HSCC for B destinations

In Figure 5.9, the reason for the savings for the supply chain with 102,400 tons to be ‘only’ between €18,000 and €90,000 is the fact that vehicle capacity becomes a restriction: this destination (Marl) cannot receive barges larger than 2,000 tons due to physical restrictions of the water depth (while the estimated storage capacity is higher and costs from Rotterdam and Moerdijk do not differ). The low (i.e. between €11,000 and €18,000) savings of the destination corresponding to 95,100 tons (Wingles), can be explained from the fact that this destination is only reachable by barges up to 1150 tons (while again, the estimated storage capacity is higher). The low savings of the destination corresponding to
49,300 tons (Oswiecim), can be explained from the fact that the cheapest modality to this destination is intermodal. Given the small difference in costs between Moerdijk and Rotterdam and the lack of physical bundling options for intermodal transport, collaborating for this destination does not yield significant savings.

A destinations are all destinations that are only reachable by tankers with high fixed costs (i.e. those with variable costs/ton up to 1/5000 of fixed costs)

**Figure 5.10: Impact of distance and volume on absolute savings from HSCC for A destinations**

In Figure 5.10 the destinations that are only reachable by tanker and moreover for which these tankers are characterized by high fixed costs are shown. These are the destinations that are most suitable for collaboration, as transport over sea is relatively expensive (see separate driver) and hence saving on the number of tankers yields considerable savings.

Moreover note that Figure 5.9 and Figure 5.10 imply a threshold whether or not to collaborate with 4C4Com on a certain lane. Given planning activities might be performed on a part-time basis or activity based (e.g. in case of a 4PL), the savings should be at least higher than the costs to coordinate a certain lane. In this case, destinations demanding less than 20,000 tons a year on a distance less than 2000 kilometers, might not be worth bundling. Yet, when the costs of coordination are order based rather than lane based, we should also be interested in the relative savings. In corresponding Figure 5.11 (which combines the destinations of Figure 5.9 and Figure 5.10 in one graph) we see a slightly different picture, which is not unsurprising since large volumes with small relative savings may still yield large absolute savings.

**Figure 5.11: Impact of distance and volume on relative savings from HSCC**
**Low maximum parcel size producers** Since we estimated rather than exactly know the maximum parcel size of participants other than SCE B.V., we investigated the effect of changing this parameter. The lower the maximum parcel size of producers due to physical or production restrictions, the higher the potential of HSCC; see Figure 5.12. The reason is that these low parcel sizes allow for physical bundling, which at its turn allows for an increase in vehicle capacity utilization and hence lower variable transport rates and less vehicles (i.e. less fixed transport costs). The higher the maximum parcel size, the lower the potential of HSCC, but savings remain to exist due to geographical bundling.

![Figure 5.12: Impact of maximum parcel size of producers on savings from 4C4Com](image)

**High maximum parcel size customers** Since we estimated rather than exactly know the maximum parcel size of customers, and this parameter moreover might be influenced in discussions with customers in practice (see recommendations in Chapter 6), we also investigated the effect of this parameter. Figure 5.13 shows that the higher the maximum (or desirable) customer parcel size, the higher the potential of HSCC, since the maximum parcel size producers can supply will lag and hence physical bundling will be profitable.

![Figure 5.13: Impact of maximum parcel size of customers on savings from 4C4Com](image)

Yet, when the parcel size customers can take is extremely low (e.g. 40 percent of our corresponding 'basis assumption'), HSCC via 4C4Com is again more attractive, because high volumes to a certain region in combination with low parcel sizes (and transport costs that are partly fixed) may justify investing in storage (in the 40% example it is profitable to invest in three storage tanks spread over Region 1). It might be hard to see in Figure 5.13, but whereas maximum parcel sizes of customers of 80% of those in the base case yield €1,470,000 savings, the savings in the 40% example are €1,960,000, due to the storage tank investments.

**High reachability** Though an aspect that cannot easily be changed, reachability also influences savings, as could be seen from the 'outliers' in Figure 5.9, where the water depth rather than the maximum parcel size of the customer became the restrictive factor. When
increasing parcel sizes is not possible, bundling may not make too much sense from that point on.

**High relative transport costs of tankers** Though of considerably less influence than other drivers, increasing transport costs of tankers yield increasing relative savings as the cost impact of bundling on these tankers is higher given the high costs/ton; see Figure 5.14. For changes in costs of other modalities, savings are more robust (see next section).

![Figure 5.14: Impact of tanker costs on savings from 4C4Com](image)

**Compatibility of end markets** When customers are supplied by only one participant, for styrene no reasons to collaborate seem to exist. Here, two out of four participants are sufficient for synergies (see next section). That is because an independent party cannot better optimize transport to a single destination than an individual producer, unless it can negotiate lower rates or has higher supply chain management skills (e.g. a 4PL) but these aspects were not incorporated in the savings. If storage locations were profitable, collaboration might still make sense if producers supply customers in the same region.

### 5.5.5 Robustness of savings

The savings of HSCC are sensitive to a number of aspects defined in the previous section, yet they are robust for others. Note that we define the robustness of the relative rather than the absolute savings, as will be explained throughout. We define robust as the impact on relative savings being <5% (if applicable: for changes up to 30% in the corresponding parameter).

**Transport costs**

*Total transport costs* When total transport costs increase (i.e. the same percentage over all modalities), absolute savings increase accordingly but relative savings remain similar (see Figure 5.15). Even when all transport costs increase by 30%, investing in storage tanks is still not profitable.

*Relative transport costs of a certain modality* When we increase costs of one modality only (apart from tankers), up to 30%, savings remain to be around 6%. Resulting shifts to other modalities are given in Table 5.7.

**Division of demand** The following two scenarios differing significantly from the original division of demand, show total savings are robust for this division and hence for ‘real’ compatibility of end markets (provided there are at least two suppliers per destination).

*Two suppliers per destination* In our ‘basis assumption’ on the division of demand we assumed all 4 participants always supply the same destination. Due to the fact this assumption may not truly represent reality, we tested a scenario in which each destination is supplied by 2 random producers out of the 4, as long as total export...
Table 5.7: Shifts to modalities as a consequence of increasing costs (up to 30%)

<table>
<thead>
<tr>
<th>Increase in costs of modality</th>
<th>Shift to modalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck</td>
<td>Blocktrain (customer 7 only)</td>
</tr>
<tr>
<td>RTC</td>
<td>Blocktrain, truck, intermodal and barge</td>
</tr>
<tr>
<td>Blocktrain</td>
<td>RTC, truck, intermodal and barge</td>
</tr>
<tr>
<td>Intermodal</td>
<td>RTC, blocktrain</td>
</tr>
<tr>
<td>Barge</td>
<td>Truck, RTC</td>
</tr>
<tr>
<td>Tanker</td>
<td>No other modality</td>
</tr>
</tbody>
</table>

Figure 5.15: Impact of total transport costs on total savings

5.5.6 Drivers of investments in storage facilities

Though we have observed investments in storage facilities are not profitable for our explorative case study, running several scenarios has provided insights into the drivers of investments in storage tanks, that need to apply *simultaneously*.

- **Low maximum parcel size customers** When the desirable parcel size of a customer is relatively small, investing in storage in the corresponding region might be worthwhile (see 'Drivers of savings’ section).

- **High total volumes to regions**

- **Large fixed part of transport costs** If transport costs to a certain destination are entirely variable per ton, it makes no sense to invest in storage locations there.
Affordable costs of storage tanks

Affordable costs of inventory holding For higher value products it is less attractive to invest in storage since the cost of inventory holding is relatively high for these products, and hence direct transport might be more cost efficient.

5.6 Discussion of Results

The results imply the business case for HSCC via 4C4Com is positive, but not yet sufficient to justify implementation. Chapter 6 contains conclusions and recommendations based on the ‘base case’ results and sensitivity analyses.

To finalize this section we have some remarks on the translation of model savings to potential real savings, to put this study into perspective. The model savings, as opposed to the potential savings when applying the 4C4Concept in real operations, might be:

- **overestimated** due to the assumption that the frequency of delivery and the volume per delivery are purely determined by the 'maximum parcel size' of customers. However, the 'maximum parcel sizes' are also the best available estimates for the 'desirable parcel sizes'.

- **overestimated** because the model is very strict in the demand of a customer and the capacity of a vehicle. This criticism is related to the better capacity utilization mechanism. In reality, rest volumes might occur less often as customers will demand 'smart' volumes (e.g. for an assumed demand of 1240 tons the model suggests to use one blocktrain and one RTC, but in reality only a blocktrain might be used for 1200 tons). To tackle this disadvantage, we also ran the model for a non-integer number of vehicles, which not only takes away these possibly 'false' savings but even more 'real' savings as it will never be possible to order e.g. 0.1 tanker and also pay 0.1 of the fixed costs of a tanker. Yet, even for a non-integer number of vehicles the savings were still 70% of the base case savings.

- **underestimated** because of the potential of the independent party, 4C4Com, to negotiate lower transport rates given higher volumes.

- **underestimated** because of a gap between the optimal/model AsIs situation and the real AsIs situation (we cannot completely verify this due to the fact only 20% of the current customers of SCE B.V. are delivery rather than pick-up customers).

- **not significantly different** in the current strategic versus operational optimization, because we expect the impact on the delta (rather than the absolute costs) will be marginal (see Appendix K). Actual demand during the year is characterized by volatility, but 4C4Com may actually pool some of this volatility among participants and hence create additional value.

- **different** as a consequence of the real parameters (in a ‘real’ collaboration) rather than the assumed parameters. Yet, sensitivity analyses described in the 'Drivers of savings' and 'Robustness of savings' sections illustrate the impact of other parameter settings.
Six

Conclusions and recommendations

6.1 Conclusions

In this master thesis project we designed an innovative business model for horizontal supply chain collaboration (HSCC) in the commodity industry. The European styrene monomer industry has been analyzed in an explorative case study to calculate a potential business case. So far, no academic studies of HSCC that exploit the unique nature of chemical commodities have been published. Yet, several companies have already applied related cases of HSCC in practice, or at least investigated opportunities to do so, which led to the first research question:

1. What elements of the business models for HSCC identified in 4 case studies are options for translation to HSCC in the commodity industry?

   Organisation aspects and desirable customer and shipper properties extracted from the case studies helped answering research question 2 and identifying aspects in need of further investigation before implementation of the business model is possible.

2. What business model can be designed for HSCC for commodities?

   4C4Com, an independent ‘black-box’ entity, enables HSCC between structural shippers of commodities in Europe, i.e. either producers that locally produce more than they consume or structural importers. These shippers need to ship a true commodity that is not transported mainly via pipeline. The total size of the shipments should be significant, at least initially, and the supply chains of the collection of shippers should be compatible. In order to make HSCC attractive, shippers should moreover experience high transport costs for a significant part of their orders, whether this is caused by a large spread of customers, inconvenient connections to preferred logistical means or transport of relatively low volumes. Finally, when it is desirable to optimize based on distance between the source and the destination of the product, the availability of it should be spread over Europe (i.e., the only criterium not being met by the styrene industry, nor any other product is currently produced by Shell that meets all criteria).

   4C4Com allows the structural shippers to optimize logistic costs and CO₂ emissions, operating based on the main principle that the total supply made available to it must meet the total corresponding demand handed over to it. This implies total demand of a customer needs to be met, no matter by what supplier(s) this is physically supplied. Original sales relations remain intact. 4C4Com collects information from all individual shippers and optimizes over the entire chain. The main principle allows 4C4Com to physically bundle volumes, swap volumes geographically and to combine by opening shared storage facilities.

   To calculate the business case of the business model, we formulated the third question.

3. What quantitative model(s) can be designed that support(s) calculating a business case for HSCC for commodities?

   Two models were designed, for the calculation of the total supply chain cost savings and for the calculation of CO₂ savings respectively. Both models can be used to calculate a business case for HSCC for commodities in general. The first is a mixed integer linear programming model, that minimizes the costs for routing certain commodities over a network of transportation services from their origins (producers or other storage facilities) to their destinations (customers,
optionally via intermediate storage facilities). It can be solved per shipper (participants + 4C4Com) both in the AsIs and the ToBe (i.e. collaborative) situation. Most important assumptions are deterministic supply and demand; maximum desirable parcel sizes of customers dictating delivery frequency and volumes; all volumes shifted to 4C4Com being delivered rather than picked up and finally the operational sequences of events and constraints of individual events being met. The constraints of the model allow the latter to be possible.

The second model is a formula based on the logic of McKinnon and Piecyk [2011], calculating total CO\(_2\) emission by taking the optimal number of vehicles from the first model as input. Again, by running it both for the AsIs and the ToBe situation savings can be calculated.

4. **What is the business case corresponding to the models in 3) applied to a specific commodity?**

We applied the business model and optimization model to the European styrene monomer industry. Specific to this industry is the cluster of non-integrated Dutch styrene producers, causing the Netherlands to have a net capacity excess of about 1,800 ktons, whereas all other European countries apart from Spain have (major) net capacity shortages. Indeed styrene flows from the Netherlands all over Europe [GTIS, 2013]. We focused on 4 Dutch industry players and built realistic profiles based on export data [GTIS, 2013], capacity data [CMAI, 2013] and data and industry knowledge available within SCE B.V. Sensitivity analyses challenged the assumptions underlying these profiles and showed savings are quite robust (see below). We observed total supply chain costs may be reduced by 6% (€1,890,000) and CO\(_2\) emissions by 11%, for 1190 ktons of styrene shifted to 4C4Com by all participants in total. Yet, these savings have to be reduced with the coordination costs of 4C4Com. Investing in shared storage tanks is not profitable for styrene, but in general might increase savings of HSCC for other commodities.

Savings are caused by physically bundled volumes, better utilization of vehicle capacity and geographical swaps. Savings increase by collaborating in cases of high volumes and distance, large volumes shipped per tanker, high maximum parcel size of customers, low maximum parcel size of producers and high reachability and compatibility of end markets. Relative savings are robust for transport costs of vehicles other than tankers and the division of customer demand over participants, as long as each customer is supplied by at least two participants.

We expect all these insights to apply to commodities in general (i.e. not to styrene only) and possibly additional mechanisms of savings apply (e.g. in case of intermediate storage tanks). Other commodities, for which supply availability is spread over Europe, might moreover lead to more significant decreases in terms of HSSE exposure.

The business case for styrene is positive but not sufficient to justify implementation. Including more products would increase savings correspondingly, while costs may only increase marginally. In fact, we estimate that including 10 other out of 18 popular commodities [ICIS, 2013] for which public data is available\(^1\), could increase savings up to €60 million. This figure is based on 6% cost savings\(^2\), which is a careful estimation. Some products will yield less savings, e.g. because the shortage - excess balance is not so extraordinar as that of styrene. Yet, other products will yield considerably more savings, e.g. because availability of product is spread all over Europe. Note that more investigation is needed to support this estimation.

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\(^1\)These 10 commodities are: aceton, base oil lubricants, benzene, butadiene, caustic soda, oxo-alcohols, phenol, polyethylene (PE), polypropylene (PP) and polystyrene. Note that PE and PP are large scale commodities (16,400 ktons and 9,500 ktons of net capacity excesses over Europe respectively [CMAI, 2013]).

\(^2\)This figure is moreover based on an average AsIs transport cost of € [Shell Chemicals, 2011, average of all commodities, corrected for strategic difference] and the sum of net capacity excesses over Europe [CMAI, 2013].
6.2 Recommendations for SCE B.V.

- Do not implement HSCC for styrene only, but investigate possibilities to include more products and find potential ‘real’ participants

The business case for styrene monomer is positive but not sufficient to justify implementation. Including more products might yield a convincing business case. We recommend staying away from tackling organisational and operational issues until this is the case. The case study learnings may then provide some initial directions.

- Solve AIMMS optimization model for other products to verify whether the AsIs situation can be improved for those products

The AIMMS model optimizes the network design of a product. Running it for other products could validate whether current supply chains have indeed truly been optimized.

6.3 Recommendations for further research

- Investigate which products meet the criteria for effective collaboration and in particular try to find a product for which supply availability is spread over Europe

The AIMMS model may be used by other industry players to calculate the potential business case for HSCC for several commodities simultaneously. We have learnt from the styrene case study that including one commodity only may not be sufficient, yet we expect the potential of products with a spread of supply availability over Europe to be higher.

- Quantify the effect of inventory pooling for HSCC

While inventory holding costs for styrene are relatively low, other (higher value) commodities of which supply availability is spread over Europe, may incur higher inventory holding costs. No model in literature effectively combines the possibility of transshipments in a pool of shippers (not to each other but to each other’s customers) with savings in safety stock [Klawer, 2012]. Yet, when the pool is able to withdraw inventory from any storage facility in the network, demand variability is pooled and hence safety stocks may be reduced. Further research may yield ways to model these effects.

- Explore potential of 4C4Com in other areas

Collaborating horizontally via 4C4Com might also yield benefits in sourcing capabilities, of logistic services (like ComLog, see Section 1.2), but maybe even of raw materials. Moreover, for the vehicles that are leased (e.g. RTCs), opportunities can be investigated for 4C4Com (or 4C4Chem) to keep a pool of vehicles.
A

Organisation charts SCE B.V.

Figure A.1: Organisation chart of Shell Downstream

Figure A.2: Organisation chart of Shell Chemicals

Figure A.3: Organisation chart of Shell Operations & HSSE
Business Model Case Studies

This attachment contains the key success factors, alternatives for shippers for collaborating, possible additions to the current business model and the business model canvases [Osterwalder and Peignier, 2010] of:

- Clearing House
- Tri-Vizor N.V.
- ARG mbh & Co. KG
- SkyTeam

B.1 Clearing House

B.1.1 Key success factors

**Number of participants** The number of participants needs to be at least 4, rather even more (in the case of polyolefins), to guarantee a spread of production over Europe, to reduce possible recognition/transparency of customer’ destinations and product origins (e.g. in case of 2 participants every volume collected via the CH at a certain participant would be supplied by the other participant) and to truly make it an industry initiative rather than to exclude certain producers.

**Interchangeability** The products included in the concept should be true commodities: members should agree on the specifications of the product, also called grades (i.e. qualities).

**Sufficient volume** The volume brought in by the participants must guarantee that the absolute savings (gains minus costs CH services) are sufficient to warrant collaboration.

**Balanced volumes** In the multilateral swaps the volumes are balanced in order to prevent having to agree on a purchase price for imbalances or being accused of market division.

**Tariffs aligned with original relations** Tariffs charged with participants should be related to the costs incurred to supply original end customers of those participants rather than to the costs incurred to supply final destinations of the styrene produced by that participant.

**Spread in customers over Europe** The concept is only viable when customers are widely spread, since this implies large transport distances and hence higher savings potential.

**Spread in producers over Europe that have product available to share** Obtaining sufficient savings from minimizing transport distances to meet a certain order is only possible when inventory can be withdrawn on a European scale. Hence, producers must be widely spread and must not transform the produced commodity to derivatives at the same / a close by location, since then inventory will not be available for sharing.

**White label product** To prevent ‘shopping’ given the CH enables structural industry optimization it is important the product cannot be traced back to the actual producer.
B.1.2 Alternatives for shippers for collaborating

Two alternatives participants have for the CH are bilateral swap agreements and withdrawal of inventory from one of their own production locations. The first option will enable the participant to obtain some savings. However, on industry scale, the sum of the savings that producers can obtain individually will be lower than what they can obtain by HSCC, as the central party allows optimizing swaps across multiple producers. This ‘multilateral’ optimization could never take place without a neutral central party like the CH, since shippers cannot directly share competitively sensitive information like cost structures or customer details [Shell, 2013]. Moreover, the willingness to conclude bilateral swap agreements in the commodity market is reduced sometimes by the fear of giving away competitively sensitive information (e.g. properties of customers) and of ‘label’ issues (e.g. does a Shell customer get a Shell or an LBI product?).

B.1.3 Possible additions to the current business model

The activities performed by the CH do not include sales to the final customer. Since the CH would be an entity of considerable size, this would be even more sensitive than the currently suggested activities in the light of anti-trust laws since firms would collaborate on the very faces of their organizations. A possible valuable addition – in case the volumes handled by the CH are considerably large – is inventory management. In its current form, the CH has no authority over inventory levels at the source, while its operations do influence them. Hence, added authority might yield more optimization opportunities. However, impact may be small due to the fact the inventory held in the commodity industry is often only a few days. The CH might consider repositioning inventory and hence investing in storage locations to optimize the overall supply chain. Finally, the CH may consider to keep its own fleet of transport means. This would make the CH an expeditor, which is a different (legal) role. This does not seem natural due to the economies of scale of existing carriers and possibly conflicting interests (maximizing versus minimizing fleet usage).
### Key Partners
- **Producers**: Members of the collaboration and at the same time also the most important customers.
- **Logistic Service Providers**: Both contractual and operational.
- **Cloud software supplier**.
- **Planning software supplier**.
- **Legal advisors and accountants**.

**MOTIVATIONS FOR PARTNERSHIPS:**
- Producers: enable value creation;
- LSPs: contractual partners as support for neutral ‘black box’ operations of Clearing House, (members no insights in destinations);
- outsourcing due to economies of scale and flexibility (core competence thinking);
- other: acquire knowledge.

### Key Activities
- **Key Partners**
  - People:
    - Analytical, relation management skills.
  - Proprietary knowledge:
    - (Office): Not strictly necessary due to nature activities.

- **Key Resources**
  - People:
    - Analytical, relation management skills.
  - IT infrastructure:
    - Linear program optimization (developed in-house).
    - Planning software.
    - Cloud software, incl. member portal with appropriate links between actors’ IT systems.
  - Proprietary knowledge:
    - (Office): Not strictly necessary due to nature activities.

- **Value Propositions**
  - Optimizing transport flows by enabling multilateral swaps.
  - Allow customers to simultaneously optimize logistic costs, service and HSSE.
  - The Clearing House (CH) creates value by enabling multilateral swaps optimized among the CH members, which yields fuel savings through reduction of transport kilometers, reduction of CO₂, reduction of transport time (transport capacity and lead time advantages), increased safety through reduction of transport kilometers of dangerous goods and reduced congestion on European roads.

- **Customer Relationships**
  - Community:
    - Online portal.
    - (Dedicated) personal assistance from CH.
    - Face to face meetings with representatives of members, if possible with all members at the same time.
  - Contracts:
    - See figure 2.1.

- **Customer Segments**
  - Producers of commodities only.
  - Only commodities can be swapped and only producers can meet the volume balancing constraint. More types of commodities, sold by the members, might be incorporated in the Clearing House concept.

- **Channels**
  - Member portal:
    - In operation phase.
  - Management team:
    - Acquiring new members, negotiating contracts and expanding services in preparation phases and in operation phase.
  - Front office:
    - Direct contact regarding declared sales volumes, rerouting of deliveries in operation phase.

### Cost Structure
- **Cost driven and value driven**.

- **FIXED COSTS**: Salaries (8 FTE: management team (2 FTE); front office (4 FTE); back office (2 FTE): €600,000).
- **Office rent and other (€200,000)**.
- **VARIABLE COSTS**: IT investments (€200,000).
- **Transport costs**.
- **During set-up: consultancy costs (€200,000)**.

### Revenue Streams
- **Transport fees**
  - Two revenue models were optional at the time the Clearing House was developed:
    1. All members pay a certain estimated amount x in advance that is expected to cover the CH expenses in a certain period; the CH pays the LSPs the actual cost; differences are restituted after.
    2. All members are invoiced for the actual transport costs.
  - Advantages of 1) above 2) may be reduced risk concerning anti-trust (in 2) volumes are linked to actual carriers, weakening the ‘black box’ effect) and increased liquidity of the CH. Advantages of 2) above 1) may be practical ease and higher transparency.

- **Clearing House operation fees**
  - A surcharge will be added to the transport fees for Clearing House services.

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**Figure B.1: Intended Business Model Canvas [Osterwalder and Peignier, 2010] of the Clearing House**
B.2 Tri-Vizor

B.2.1 Key success factors

**Number of participants** Given that synergies exist, 2 participants can be sufficient for a successful community, provided they do not include exactly the same product. If this is the case, at least 3 participants are needed to prevent being able to trace back individual volumes, which is possible due to aggregated volumes transported by the carrier being known via the transport invoices. Also, the community legally must allow new (and leaving) entrants if this adds value.

**Compatibility between transport lanes** The transport lanes brought in the horizontal collaboration by the shippers must sufficiently coincide to allow transport cost reductions. This compatibility might be in terms of flows in the same or in the opposite direction.

**Volume** Participating shippers should bring in sufficient volume. As a rule of thumb, this is at least 25 LTL or 45 FTL per shipper per transport lane per year (round trip profits are lower than profits from LTL combinations).

**Compatibility between delivery frequencies** Only volumes for which the delivery frequency is compatible can be bundled, which may require flexibility of the shippers’ customers. Note that the total number of deliveries does not need to be the same (e.g. one shipper may bundle its products with the weekly deliveries of another shippers just once every two weeks).

**Compatibility between nature of goods** The nature of the goods that are bundled should be such that these goods can be transported in the same vehicle.

B.2.2 Alternatives for shippers for collaborating

Shippers may try to get (closer to) FTL themselves by reorganization of their own supply chain, but this may not always be possible nor cost efficient. There is no alternative for bundling flows between shippers without some form of formal collaboration through a central party due to anti-trust laws. The most natural alternatives shippers have for collaborating with Tri-Vizor apart from bringing in another third party (e.g. indirect competitor of Tri-Vizor, Caroz) is to investigate the opportunities for a suitable joint venture form. From a legal and practical perspective this might be more cumbersome. It might not even be cheaper as a J.V. also needs to be staffed and does not have economies of scale like Tri-Vizor. Also, especially when partners are competitors in the activities included in the collaboration, the role of a trustee within a community has been evaluated as very valuable [Palmer et al., 2012], in the areas of e.g. contract management, supply and operation of the supporting IT systems, advice on entry and exit rules, implementation of fair gain sharing and organisation of regular communication.

B.2.3 Possible additions to the current business model

The activities performed for shippers currently working with Tri-Vizor do not include a direct control over the properties of flows (e.g. origin, destination, delivery frequency (some indirect influence), volume, push/pull), due to the fact the individual shippers remain responsible for their individual customer portfolios. Also, Tri-Vizor’s activities do not include a control over transport contracts, as these remain within the hands of the shippers. The main reason is the risk or liability involved, which is hard (and hence illogical) to bear as a start-up performing virtual operations. When Tri-vizor owns the transport contracts it becomes an expeditor or 4PL and would have to meet entirely different legislation, get additional insurances etcetera.
Figure B.2: Business Model Canvas [Osterwalder and Peigner, 2010] of Tri-Vizor N.V.
B.3 ARG

B.3.1 Key success factors

**High entry barrier** Due to the enormous investments related with building a pipeline, ARG was and remains to be the only common carrier ethylene pipeline owner in the area between Antwerp and Cologne and the Ruhr area. This has ensured the profitability of the pipeline as ARG does not have to compete with other pipeline companies.

**Common ethylene specification** The specification of ethylene is on the table regularly. Agreement on a common ethylene specification and meeting this specification (measured by many gauges) is essential to guarantee the interchangeability of the product.

**Sufficient imbalance in supply and demand** The location of the pipeline partly guarantees its throughput: an area where several procurers and consumers (naturally both are necessary) are located. However, if demand drops and plants close, the throughput might at a certain point become insufficient to justify ARG’s existence.

B.3.2 Alternatives for customers for collaborating

Ethylene cannot be moved over land other than via pipeline due to its dangerous nature. Since ARG owns the only ethylene pipeline that connects several companies located between Antwerp and Cologne and the Ruhr area, transport between companies is only enabled via ARG. Naturally, connected companies to ARG will try to save costs, which might be enabled by time swaps (e.g. as an alternative for the lend and depot contract) and geographical swaps. Suppose a customer A of ARG in Gelsenkirchen transports ethylene for SCE B.V. to a customer B in Wesseling. Around the same time, SCE B.V. transports ethylene to a customer C in Geel for customer A. Though both parties still have to contract ARG, they obtain substantial transport savings versus the situation in which no bilateral agreements between party A and SCE B.V. had been concluded and both had commissioned transport of ethylene via ARG from their own supply points to their original customers. Indeed, ARG minimizes flows physically, but not financially (as, by using their current business model, ARG has an interest in maximizing rather than minimizing flows via the ARG pipeline grid).

B.3.3 Possible additions to the business model

Like the activities performed by Tri-Vizor, the activities performed for customers of ARG do not include a direct control over the properties of flows (e.g. origin, destination, delivery frequency, volume, push/pull). This does not seem natural since the imbalances are related to the actual produced amounts of ethylene (derivative) plants and these can change unexpectedly. Direct control would therefore imply ARG taking over all companies, without creating additional supply chain optimization opportunities in the area the ARG pipeline covers. The added value for ARG of holding extra inventory on top of the 8 ktons seems to be low, as unexpected/short-term imbalances in supply and demand of all parties involved guarantee willingness to collaborate and hence demand in the system can nearly always be met. Given this, holding extra inventory (for which no strategic location can be determined as the pipeline is ‘one big storage tank’) would imply ARG enters the entirely different business of being a trader. Also, ARG could consider to operate the control room and to perform maintenance itself, but the costs of this probably justify outsourcing. Finally, a change rather than an addition to the business model could be the replacement of the fixed basic rate and the variable distance-related rate by an increased fixed basic rate, as the variable rate physically does not seem to make sense.
### Key Partners
- PPS control room
- PPS operations & maintenance
- Tax experts
- Legal experts
- Easement rights experts

### Key Activities
- Supplying pipeline capacity for ethylene transport by concluding transport contracts
- Enabling actual transport of ethylene by communicating transport plannings to the control room

### Value Propositions
- Allow customers to transport ethylene between companies located in the region between Antwerp and Cologne and the Ruhr area to meet short and long term supply imbalances
- Transport of ethylene via land is not allowed other than via pipeline. ARG enables transport of ethylene justified by a combination of supply and demand. This combination can either be opportunistic (e.g. created by a short term imbalance) or based on longer term relations (e.g. a long term contract between a supplier and a consumer and a corresponding long term contract with ARG)

### Customer Relationships
- **Personal assistance**
  - Contact by e-mail or phone with customers
  - Quality circles: biennial face to face meetings between ARG and dispatchers of companies connected to the grid
- **Contracts**
  - See figure 2.3

### Key Resources
- People
  - Analytical, relation management skills
- IT infrastructure
- Pipeline
  - Not: valve stations (owned by connected companies themselves)
- (Office)
  - Not strictly necessary due to nature activities

### Channels
- Website
- In-house force
  - Direct contact via e-mail and phone
- Pipeline

### Customer Segments
- Suppliers and combined suppliers/consumers
- Consumers
- Third parties

### Cost Structure
- Cost driven and value driven
  - **FIXED COSTS:**
    - Salaries (9 FTE: managing director (1), dispatching (3), controlling (2), accounting (2), secretary (1))
    - Office rent
    - Insurance for leaks, accidents etc.
    - Pipeline depreciation (not anymore)
    - PPS control room
  - **VARIABLE COSTS:**
    - IT investments
    - PPS Operations & Maintenance
    - Third party payments with respect to insurances, legal, tax and easement rights issues

### Revenue Streams
- Transport rates
  - Dependent on timely conclusion of the contract, contract duration and projected transported amounts.
  - **NOT** dependent on whether the customer is a shareholder or not.
  - Comprised of:
    - Fixed basic rate
    - Variable distance-related rate
  - Rent rates of quality measuring equipment (small)

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**Figure B.3: Business Model Canvas [Osterwalder and Peigner, 2010] of ARG mbh**
B.4 SkyTeam

B.4.1 Key success factors SkyTeam

**Number of participants** The number of members needs to be at least 4 for SkyTeam to be able to provide any value beyond a joint venture.

**Network expansion** A member needs to extend the existing network under the SkyTeam umbrella for SkyTeam to be able to keep the same value propositions (see Figure B.4).

**Significant customer experience** The effect of SkyTeam’s activities on the final customer, i.e. the passenger, needs to be significant in order for the individual airlines to value SkyTeam and hence to remain to be a member.

**Participants meeting requirements** Members must meet certain customer service standards, safety levels (IOSA certificate) and requirements with respect to technology compliance in order to preserve the quality label SkyTeam represents.

B.4.2 Alternatives for customers for collaborating with SkyTeam

The alternatives for individual airlines relate to Figure 2.5. An airline can start a joint venture, however – since a JV is the closest form of collaboration – there will be a limit on the number of participants and hence on the network benefits. An airline can also collaborate with an alliance other than SkyTeam. Finally, an airline can collaborate loosely by concluding interline agreements only. However, many customers today, particularly those travelling on business, demand a seamless international travel experience from ‘anywhere to anywhere’. No airline is able to efficiently provide a service that is both international and frequent based on its own services. The most noteworthy independent airlines are many Middle Eastern airlines, likely because of their high cash positions and difficulties to align their luxury on-board experience with other airlines [Carlson Wagonlit Travel, 2012].

B.4.3 Possible additions to the current business model of SkyTeam

From an anti-trust perspective no logical additions to the current business model of SkyTeam can be devised. The existence of joint ventures can clearly be justified by their representing a closer form of collaboration and it will not be possible – both from a legal and a practical perspective (see subsection 3.3.2) – to establish a joint venture that entails a global network. An extension of the projects to enhance the customer experience is in the very core of SkyTeam and hence does not represent an addition to its current business model.
### Key Partners

**Airlines**
Members of the collaboration and at the same time also the most important customers

**IT suppliers**

**MOTIVATIONS FOR PARTNERSHIPS:**

- **Airlines:** enable value creation, IT suppliers: acquire knowledge

### Key Activities

**Managing platform for individual airlines**
Provide a network for individual airlines to collaborate and conclude e.g. codesharing agreements

**Defining and supervising projects**
SkyTeam identifies new projects together with (a part of) the members and executes them or provides the framework for how the individual airlines can execute them. Those projects are aimed at enhancing the seamless travel experience of customers (e.g. frequent flyer program benefits across members) and save costs (e.g. co-location of check-in and ticketing areas).

**Marketing**

- **During early years of SkyTeam:** focus on extending network by involving new members (scale). Now: focus on extending services (scope), e.g. SkyTransfer, SkyPriority, seamless travel experience.

### Key Resources

**People**
Analytical, relation management skills

**IT hub (Office)**
Not strictly necessary due to nature activities

All other resources to perform actual operations are in the hands of the individual airlines

### Value Propositions

**Facilitate the extension of networks of individual members**
Once an airline joins SkyTeam, the airline can increase its network through alliance partnerships with several individual airlines, such as codesharing. SkyTeam can be considered an umbrella organisation facilitating these relations.

**Strengthen quality brand of individual members**
Members gain exposure in new key regions of the world and carry the quality label 'SkyTeam'. Also, as a project organisation, SkyTeam is fully committed to improving the customer experience by initiatives such as SkyPriority, SkyTransfer and SkyPost. Knowledge and best practice sharing helps improving customer service and safety and hence in the end strengthens the brand and thus revenues of individual airlines.

**Provide members ways to save costs**
Airport co-location, where ≥3 member airlines share check-in and ticketing areas, ground handling staff and equipment and lounge facilities, allow members to enjoy cost savings. Also, SkyTeam provides members a way to share knowledge and best practices on operational efficiencies.

### Customer Relationships

**Personal assistance**

- **Community**
  - Face to face or videoconferencing meetings with representatives of member airlines and SkyTeam office
  - IT hub linking members

### Customer Segments

**Airlines**
Individual airlines are 'customers' (members) of SkyTeam. A potential member airline, apart from extending the existing network (for itself and as a whole), must meet a set of requirements w.r.t.:

- Customer service standards
- Safety levels (IOSA certificate)
- Technology compliance

Also, a member should introduce new projects to SkyTeam.

### Channels

**Website**
SkyTeam Management Team
Direct contact with (potential) member airlines

### Cost Structure

Cost driven and value driven

**FIXED COSTS:**
Salaries (30 employees)
Office rent and other

**VARIABLE COSTS:**
Project investments apart from manpower

### Revenue Streams

**Contribution fees**

- Members pay contribution to co-operative SkyTeam. The costs are divided based mainly on included passenger kilometers of individual members.

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Figure B.4: Business Model Canvas [Osterwalder and Peigner, 2010] of SkyTeam
C

Overview ARG pipeline

Figure C.1: Overview ARG pipeline grid

Figure C.2: Overview supply and extraction points ARG pipeline
Product criteria for suitability HSCC

Products that can benefit from HSCC via 4C4Com need to have the following characteristics. The product is:

1. A true commodity and agreed on in terms of specifications
2. Currently not mainly transported via pipeline
3. Shipped in significant volumes*
   This means there is an imbalance in supply and demand. Supply may be clustered or spread (see criterion 6). *The volume made available to the 4C4Com by all initial participants needs to be at least such that it makes up for the costs of operating 4C4Com, as will become evident from the business case. However, when more participants or commodities are included, smaller volumes might be sufficient to collaborate (given agreement on a fair cost sharing mechanism).
4. Demanded by included customers to more than one participant and in compatible delivery frequencies
5. Incurring high transport costs for at least a part of its orders, due to
   - A spread of customer demand for the product over Europe: large distances to customer’s locations
   - Supply or demand locations of the product having inconvenient connections to preferred logistical means
   - Low volumes per order for the product

It may also be desirable to optimize based on distance between the source and the destination of the product (original interpretation of ‘combine at the source’, we now know combining at the source may also occur for other geographical swapping purposes), which may lead to significant savings as learnt from the Clearing House project. Then, the product moreover needs to meet the following requirement:

6. Supply availability of the product is spread over Europe, either because it is stored in Europe (by a structural importer) or produced by a plant that locally produces more than it consumes.
Case selection criteria table

E.1 Measuring criteria

The evaluation of the criteria that supported the product selection is summarized in Table E.1.

Criterium 1 Checked by interviewing several supply managers responsible for the products.

Criterium 2 Checked for SCE B.V. by analyzing Shell Chemicals [2011] and for other shippers by interviewing several supply managers responsible for the products.

Criterium 3 Measured by comparing volumes of products relative to those of other products. Finally note that this criterium could only be checked at SCE B.V. but is indirectly also checked for other shippers by criterium 4.

Criterium 4 Hard to measure in this particular case study as it is still explorative, but estimates for meeting this criterium can be partly based on a comparison of export numbers [GTIS, 2013] and Shell Chemicals [2011] and partly based on results from sensitivity analyses. That is, for the initial selection we did not explicitly evaluate this criterium but we did take it into account in the more detailed analysis.

Criterium 5 Measured in two ways:

1. A spread of customer locations over entire Europe measured by the number of European countries SCE B.V.’s serves [Shell Chemicals, 2011]

2. The maximum transport cost of 80 percent of the ‘deliver’ sales volume (ordered from low to high based on transport cost) as a percentage of the maximum transport cost of the total ‘deliver’ volume [Shell Chemicals, 2011]. To prevent biasing the results with one customer, the latter maximum transport cost was calculated as an average of the transport cost of the 1 percent highest transport cost sales volumes. This criterium was included to check the ‘80-20’ Pareto hypothesis, that in this case states 80 percent of the volume is delivered for 20 percent of the maximum transport cost, implying the most efficiencies can be gained in the other 20 percent of the volume.

Criterium 6 The spread of shippers over Europe was measured by the number of West- and Central-European countries in which the commodity is produced (note that this is not equal to the number of production locations as the latter number will be larger) [CMAI, 2013]. Note that we later redefined this criterium to the way it has been formulated now to include the property that producers spread over Europe need to be producers that locally produce more than they consume.

For practical reasons, only products that were at least produced either in Moerdijk or in Pernis (the two Dutch production locations of SCE B.V.) were included in the analysis.
### Table E.1: Products produced a.o. in Moerdijk or Pernis and their scores on criteria

<table>
<thead>
<tr>
<th>Product</th>
<th>SC locations Europe</th>
<th>Commodity</th>
<th>Prim. not pipeline</th>
<th>kton cap SCE</th>
<th>Abs. TC SCE(^1)</th>
<th>Abs. TC SCE delivery cust. (incl. stock) movement(^2)</th>
<th>TC C2S SCE(^3)</th>
<th># prod loc</th>
<th># cust loc</th>
<th>max transp. cost 80% volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>ethylene(^4)</td>
<td>Moerdijk, Wesseling, Mossmorran</td>
<td>yes</td>
<td>no</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>propylene polymer grade(^1,2)</td>
<td>Moerdijk, Pernis, Schwedt, Wesseling</td>
<td>no</td>
<td>yes</td>
<td></td>
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<tr>
<td>butadiene</td>
<td>Moerdijk</td>
<td>yes</td>
<td>yes</td>
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<tr>
<td>isoprene(^3)</td>
<td>Pernis</td>
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<td>dicyclopentadiene</td>
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<tr>
<td>ethylene oxide</td>
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<td>ethylene glycols</td>
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<td>largest: MEG</td>
<td>Moerdijk</td>
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<td>styrene monomer(^4)</td>
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<tr>
<td>propylene oxide(^4)</td>
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<td>hydrocarbon solvents</td>
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<td></td>
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</tr>
<tr>
<td>many grades, small volumes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

1 Excluding plants from competitors where Shell has capacity rights,
2 37.5% of PCK Schwedt,
3 Not available for Europe in Shell Chemicals [2011],
4 50% of production SMPO2 Elba Moerdijk (JV BASF),
5 All 'import' dispatch sites were left out of consideration, in actual research phase this needs refining (of 2012 data that will then be available) due to data pollution,
6 Figure biased due to a large part of the customers picking up the material,
7 Excluded from further analysis due to small (non-pipeline) volumes or low customer location diversity,
8 Small parties: France (16 ktons), Sweden (5 ktons), Romania (32 ktons).

Sources: Shell Chemicals [2013], Shell Chemicals [2011], SRI International [2012], CMAI [2013]
F

Case study supply chain at SCE B.V.

This appendix discusses production, inventory, demand and transport management of styrene monomer at SCE B.V.

F.1 Production

F.1.1 Process

The conventional method for producing styrene is the alkylation of benzene with ethylene followed by dehydrogenation. The exception, as applies to the styrene produced in Moerdijk (and produced by key players LBI and Repsol), is the process to co-produce styrene and PO via the oxidation of propylene by ethylbenzene hydroperoxide, also known as the ‘SM/PO’ process. Styrene monomer is produced by SCE B.V. in Europe in Moerdijk only, in the MSPO1 and MSPO2 plant. MSPO1 is completely Shell owned and has the capacity to produce \( \Box \) ktons (500 ppm ethylbenzene) a year. MSPO2 is owned by Ellba B.V. and has the capacity to produce \( \Box \) ktons (100 ppm ethylbenzene: higher quality) a year, so \( \Box \) ktons for Shell only.

F.1.2 Production management

Actual production is based on an annual plan meeting taking place between the supply and manufacturing department, with inputs from the commercial department. In this meeting, the annual production plan and the preferred division over spot and contract demand is discussed. The worse the market prospects, the higher the effort to capture more volume in contracts. Monthly sales & operations planning meetings result in a fixed production schedule on a rolling horizon of three months (deviations result only from unexpected disruptions on the supply or demand side). Weekly meetings between the trading, commercial and supply department concern exact volumes customers are going to lift that week (contractual amounts are monthly).

F.2 Inventory

Storage tanks

MSPO1 has two storage tanks with a total capacity of \( \Box \) ktons. MSPO2 has three storage tanks with a total capacity of \( \Box \) ktons. Currently there are no other styrene storage tanks (terminals) owned/rented by SCE B.V. in Europe.

F.2.1 Inventory management

The MSPO plants run close to capacity due to sufficient demand for PO. The end of month target level of inventory in the MSPO tanks has no formal underlying calculation (and reasons for reducing it have been recently brought up by an analyst from Shell Eastern Petroleum Pte Ltd). The supply manager determines the target level based on three components: dead stock (non-pumpable stock, about \( \Box \) per tank), safety stock for the supply side (based on experience with unexpected short supply disruptions) and safety stock for the demand side. The latter safety stock is based on a worst case scenario in which all customers lift at the same time.
of the month. Though demand volatility is partly reduced by ‘equally spread’ arrangements in contracts, there is some flexibility, especially for customers that only ship once a month, in deciding about the moment to lift depending on price developments. Also, the arrival of tankers is never certain. Inventory levels beyond or below the target level (up to 20% deviations) do not necessarily initiate action depending on market dynamics insights of the supply manager.

**F.3 Demand**

SCE B.V. experiences two types of demand:

- **Contracts** About □% of all demand: 1-3 years; □□□%: >3 years. Each contract includes a □% unpunzalized volume optionality and is based on equally spread lifting.

- **Spot** Roughly □□% of all demand.

Swaps are not noticed here as they are a means of satisfying the demand (either caused by an underlying contract or on the spot). Currently SCE B.V. has □□□□□□□□□□□□□□□□□□

**F.4 Transport**

Nearly □% of SCE B.V.’s customers are pick up customers [Shell Chemicals, 2011]. Modalities currently used for both delivery and pick-up customers of SCE B.V. are given in Figure 5.4. SCE B.V. does not own any vehicles itself.

For transport over land, orders are communicated either via customer relations coordinators or via e-business (Elemica or customer lounge website). Orders are handled automatically from customers to LSP. Confirmation of the order takes place based on a number of checks like product availability and invoice overdue. Truck companies drive Full Truck Loads (FTL). They do not have to reserve time windows at Moerdijk, only the day of loading is known.

For transport over water, orders are communicated via supply. Orders have not been automated so far since they are subject to more uncertainty and arranged for higher volumes. In order to manage inventory levels at MSPO1 and MSPO2 customers that do not need 100 ppm styrene are flexibly and manually allocated to these tanks. Marine arranges spot / long term contracts with tankers and barges and is responsible for jetty planning. Customers and SCE B.V. – depending on pick-up/delivery – have to take the notice time, the laycan (the time window in which the ships are ensured of a possibility to load, e.g. 5 days) and the leadtime into account to ensure ship, jetty and product availability.
Case study demand data assumptions

Assumption: Demand/consumer (city) to SCE B.V. equals demand given in Appendix H

Based on the customer profitability data of SCE B.V. 2012 [Shell Chemicals, 2012], export data [GTIS, 2013] and net capacity shortages of cities [CMAI, 2013] the demand per consumer for SCE B.V. was estimated.

The demand per country for SCE B.V. equals the demand per country as given in Shell Chemicals [2012], corrected for the demand volume for which the destination was reported to be unknown, yielding \( d_{SCE,country} \). The ‘unknown’ volume of 177 kt ons is assumed to be divided over countries according to the export to that country in scope \( (d_{country}) \) [GTIS, 2013] proportional to the total Dutch export in scope [GTIS, 2013]. The ”Dutch” demand per styrene consumer (city) \( i \) within a certain country, \( d_i \), is equal to percentage \( y \) of the total Dutch export to that country within scope:

\[
d_i = d_{country} \cdot y, \quad \text{where } y = \frac{\text{Net capacity shortage } i}{\text{Net capacity shortage country}}
\]

where the net capacity shortage of a city is based on the capacity shortage of that city according to CMAI [2013] corrected for capacity excesses in that country.

The demand per styrene consumer (city) to SCE B.V., \( d_{SCE,i} \), equals:

\[
d_{SCE,i} = d_i \cdot z_{SCE,country}, \quad \text{where } z_{SCE,country} = \frac{d_{SCE,country}}{d_{country}}
\]

Assumption: Demand/consumer (city) to BASF, LBI and Bayer equals demand given in Appendix H

Based on the export data [GTIS, 2013], the respective production capacities of BASF, LBI and Bayer in the Netherlands [CMAI, 2013] and net capacity shortages of cities [CMAI, 2013] the demand per consumer for each of these 3 participants was estimated.

That is, the demand per country for the Dutch locations of BASF, LBI and Bayer (participant \( p \)) equals:

\[
d_{p,country} = (d_{country} - d_{SCE,country}) \cdot \text{production capacity share of } p, \quad \text{where}
\]

the production capacity share of \( p \) equals the production capacity of \( p \) in the Netherlands divided by the total production capacity of BASF, LBI and Bayer in the Netherlands as given in Table 5.2.

Then, the demand per styrene consumer (city) to BASF, LBI and Bayer, \( d_{p,i} \), equals:

\[
d_{p,i} = d_i \cdot z_{p,country}, \quad \text{where } z_{p,country} = \frac{d_{p,country}}{d_{country}}
\]
**Table H.1: Demand data styrene monomer case study Europe**

**WORLD STYRENE CAPACITY INTEGRATION FOR 2013**

*Nameplate Capacity to Consume STYRENE [CMAI, 2013]*. Dutch export [GTIS, 2013] and supply and demand calculations.

<table>
<thead>
<tr>
<th>COMPANY</th>
<th>LOCATION</th>
<th>Styrene Cap. (KT)</th>
<th>500 ppm cons. * (KT)</th>
<th>100 ppm cons. * (KT)</th>
<th>NET cor. (KT)</th>
<th>Max. parcel (KT)^3</th>
<th>Exp. NL (avg KT '10-'12)</th>
<th>Exp. RM (KT)</th>
<th>* Incl. grouped ppm (TONS)</th>
<th>Indiff. ppm (TONS)</th>
<th>100 ppm Shell adj. CP '12 (TONS)</th>
<th>Shell (TONS)</th>
<th>BASF (TONS)</th>
<th>LBI (TONS)</th>
<th>Bayer (TONS)</th>
</tr>
</thead>
</table>

*Note:* The table above contains the demand data for styrene monomer in Europe, including company names, location, nameplate capacity, and additional data points such as consumption rates and supply calculations.
### World Styrene Capacity Integration for 2013

Nameplate Capacity to Consume Styrene [CMAI, 2013], Dutch export [GTIS, 2013] and supply and demand calculations.

<table>
<thead>
<tr>
<th>COMPANY</th>
<th>LOCATION</th>
<th>Styrene Cap. 500 ppm cons. (KT)</th>
<th>100 ppm cons. (KT)</th>
<th>NET cor. (KT)</th>
<th>Max. parcel (KT)</th>
<th>Exp. NL (avg KT '10-'12)</th>
<th>Exp. RM ppm (TONS)</th>
<th>Indiff. ppm (TONS)</th>
<th>100 ppm CP '12 (TONS)</th>
<th>Shell adj. (TONS)</th>
<th>BASF (TONS)</th>
<th>LBI (TONS)</th>
<th>Bayer (TONS)</th>
</tr>
</thead>
</table>
### Nameplate Capacity to Consume STYRENE [CMAI, 2013], Dutch export [GTIS, 2013] and supply and demand calculations

<table>
<thead>
<tr>
<th>COMPANY</th>
<th>LOCATION</th>
<th>Styrene Cap. (KT)</th>
<th>500 ppm cons. (KT)</th>
<th>100 ppm cons. (KT)</th>
<th>NET cor. (KT)</th>
<th>Max. parcel (KT)</th>
<th>Exp. NL (avg KT)</th>
<th>Exp. RM (TONS)</th>
<th>&quot;Incl., grouped ppm (TONS)</th>
<th>Indiff. ppm (TONS)</th>
<th>100 ppm (TONS)</th>
<th>Shell adj. CP '12 (TONS)</th>
<th>Shell BASF (TONS)</th>
<th>BASF LBI (TONS)</th>
<th>Bayer (TONS)</th>
</tr>
</thead>
</table>
### World Styrene Capacity Integration for 2013

Nameplate capacity to consume styrene [CMAI, 2013], Dutch export [GTIS, 2013] and supply and demand calculations.

<table>
<thead>
<tr>
<th>COMPANY</th>
<th>LOCATION</th>
<th>Styrene Cap. (KT)</th>
<th>500 ppm cons. (KT)</th>
<th>100 ppm cons. (KT)</th>
<th>NET cor. (KT)</th>
<th>Max. parcel (KT) (^1)</th>
<th>Exp. NL (avg KT '10-'12)</th>
<th>Exp. RM (KT)</th>
<th># Incl. grouped ppm</th>
<th>Indiff. ppm</th>
<th>100 ppm CP '12</th>
<th>Shell adj.</th>
<th>Shell (TONS)</th>
<th>BASF (TONS)</th>
<th>LBI (TONS)</th>
<th>Bayer (TONS)</th>
</tr>
</thead>
</table>

**Notes:**
- \(^1\) Parcel: Grouped
Table I.1: Properties of production, dummy, customer and optional storage nodes for styrene in Europe

<table>
<thead>
<tr>
<th>Name</th>
<th>City</th>
<th>NodeType</th>
<th>Node</th>
<th>Region</th>
<th>Max parcelsize</th>
</tr>
</thead>
</table>

Case study optimization model parameters and sets

J.1 Sets

C  $cu_1 - cu_{29}$: For a full description of the names and locations of these customers see Appendix I.

P  $pr_1, pr_2, pr_3, pr_4$: representing Shell, BASF, LBI and Bayer respectively. For a full description of the names and locations of these structural shippers (in this case producers) see Appendix I.

S  $st_1 - st_{34}$: For a full description of the names and locations of these optional storage nodes see Appendix I.

K  $co_1, co_5$: representing styrene 100 ppm and styrene 500 ppm respectively.

D  $du_1, du_2$: representing Rotterdam (for physical bundling on tankers, might just as well be Moerdijk but for reasons of simplicity we chose one location and Rotterdam is not physically restricted) and Kijfhoek (for physical bundling of RTCs to form one blocktrain). Note that due to small volumes the strategic optimization model will rarely send flows via Kijfhoek (and rather have all flows originate from one producer) but in operation there might be reasons to do so.

N  Collection of all nodes mentioned above.

A  Collection of all arcs between the nodes mentioned above.

V  $v_1$-$v_{11}$: Vehicle types – used by (customers of) SCE B.V. for the supply of styrene monomer and hence assumed to be used by all participants in general – are shown in Table J.1. The reason to split the modality ‘barge’ into 4 types is different costs per type of barge and the reason to split the modality ‘tanker’ is the physical restriction of Moerdijk (depth of Hollands Diep) of tankers up to 6,000 tons. The vehicle ‘LoadDummy’ was introduced to shift volume from producers in Rotterdam to the dummy node Rotterdam, and from storage tanks at a certain location to customers located at the same location.

J.2 Parameters

$d_i^k$: See Appendix H for the demand per node for each producer, where locations map to customer nodes as represented in Appendix I.

$o_i^k$: Depends on scenario combination of 100 ppm assignment and region(s) shifted to 4C4Com (e.g. 100 ppm styrene is supplied by all 4 participants and Region 1 is shifted to 4C4Com). $o_i^{co_1} + o_i^{co_5}$ always equals the supply given in Table 5.2 in the main text. In the AsIs situation, the supply of commodity $k$ per producer $i$ equals the sum of demand of commodity $k$.

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Table J.1: Vehicle types and properties

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Index</th>
<th>Vehicle capacity (TONS)</th>
<th>gCO2/tonne-km</th>
<th>Average utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck</td>
<td>ve1</td>
<td>27</td>
<td>62</td>
<td>1</td>
</tr>
<tr>
<td>Rail Tank Car (RTC)</td>
<td>ve2</td>
<td>60</td>
<td>22</td>
<td>1</td>
</tr>
<tr>
<td>Blocktrain (i.e. 20 RTCs)</td>
<td>ve3</td>
<td>1200</td>
<td>22</td>
<td>1</td>
</tr>
<tr>
<td>Barge up to 1,150 tons</td>
<td>ve4</td>
<td>1150</td>
<td>31</td>
<td>0.7</td>
</tr>
<tr>
<td>Barge up to 1,500 tons</td>
<td>ve5</td>
<td>1500</td>
<td>31</td>
<td>0.7</td>
</tr>
<tr>
<td>Barge up to 2,000 tons</td>
<td>ve6</td>
<td>2000</td>
<td>31</td>
<td>0.7</td>
</tr>
<tr>
<td>Barge up to 3,000 tons</td>
<td>ve7</td>
<td>3000</td>
<td>31</td>
<td>0.7</td>
</tr>
<tr>
<td>Tanker up to 6,000 tons</td>
<td>ve8</td>
<td>6000</td>
<td>18.8</td>
<td>0.64</td>
</tr>
<tr>
<td>Tanker up to 12,000 tons</td>
<td>ve9</td>
<td>12000</td>
<td>10.88</td>
<td>0.64</td>
</tr>
<tr>
<td>IMrail</td>
<td>ve10</td>
<td>27</td>
<td>26</td>
<td>1</td>
</tr>
<tr>
<td>LoadDum</td>
<td>ve11</td>
<td>12000</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

1Sources: McKinnon and Piecyk [2011] (all vehicle types but tankers) and Defra [2011] (tankers), the latter is an official data source reported in McKinnon and Piecyk [2011] and provides more specific information regarding tanker size and contents. 2Sources: Industry knowledge and Defra [2011].

t-k

See Appendix I.

\( \gamma_{jk} \) Due to the enormous number of combinations this data is not mentioned separately but can be viewed in the 'Commodity_Europe_Data.xls' excel file accompanying this project. Depending on the scenario this binary reachability parameter might change for those OD pairs including dummy nodes (e.g. reachability to and from dummy nodes is zero in the AsIs situation). See Table J.2 for the source for the reachability parameters per vehicle.

c-k

See Table J.1.

f-k

See 'Commodity_Europe_Data.xls'. The fixed costs are assumed to be the same for both grades. Separate data was provided for flows originating from Moerdijk and Rotterdam. In Table J.2 the data sources or formulas yielding \( f_{ij}^{k} \) are mentioned. All data coming from sources other than SCE B.V. are based on spot prices rather than contract/negotiated prices (and may hence be slightly overestimated). All data includes estimates for loading, unloading and 10% demurrage.

c-k

See 'Commodity_Europe_Data.xls'. The variable costs are assumed to be the same for both grades. In Table J.2 the data sources or formulas corresponding yielding \( c_{ij}^{k} \) are mentioned. Note that if costs are variable over distance they are fixed in the model (as the distance between two nodes is fixed), the variable part relates to variable volumes. All data coming from sources other than SCE B.V. are again based on spot prices.

\( \alpha_{i}^{k} \) For each node \( i \in S \) the value of 1 and 0 was tried.

\( y_{i}^{k} \) Options are 0, 3,000 or 6,000 tons for both styrene grades.

\( i_{i}^{k} \) 3,000 tons and 6,000 tons for storage tanks with a capacity of 3,000 tons and 6,000 tons respectively, based on storage contracting knowledge available within SCE B.V. and based on Rubis Terminal B.V. [2010].
Appendix J. Case Study Optimization Model Parameters and Sets

- $m_i$ — tankturns for close by locations (up to 3 days per tanker/1500 kilometers), tankturns for medium close by locations (up to 7 days per tanker/1900 kilometers) and tankturns for far away locations, based on storage contracting knowledge available within SCE B.V.. E.g. opening a tank of 3,000 tons implies a maximum throughput of $3,000 \text{ per year}$.

- $f^k_i$ — for 3,000 tons and $e^k_i$ for 6,000 tons, independent of the styrene grade, based on storage contracting knowledge available within SCE B.V. and based on Rubis Terminal B.V. [2010].

- $c^k_i$ — assumed to be the same for all storage nodes and both styrene grades – which is derived from the storage contracting knowledge that nitrogen usage equals 4 times the throughput on average (nitrogen costs $e^k_i$ per $m^3$ [Rubis Terminal B.V., 2010]).

- $u^k_i$ — same value for all storage nodes and styrene grades.

- $r$ —% as used by the financial department of SCE B.V..

- $d^k_{ij}$ — Google maps distances for all vehicles except tankers, for which distances were given by Eastport Maritime. See ‘Commodity_Europe_Data.xls’.

- $\rho^k$ — see Table J.1

### Table J.2: Vehicle transport costs (TC) and reachability sources/formulas

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Source of reachability</th>
<th>Source of TC</th>
<th>Variable/fixed TC</th>
<th>Formula for TC in €</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck</td>
<td>Every customer is assumed to be reachable by truck</td>
<td>SCE B.V. styrene distribution file 2012</td>
<td>Fixed</td>
<td>—</td>
</tr>
<tr>
<td>RTC</td>
<td>Transpetrol</td>
<td>SCE B.V. general distribution file 2012</td>
<td>Fixed</td>
<td>—</td>
</tr>
<tr>
<td>Blocktrain</td>
<td>Transpetrol</td>
<td>SCE B.V. general distribution file 2012; 20% discount blocktrain: Transpetrol</td>
<td>Fixed</td>
<td>—</td>
</tr>
<tr>
<td>All barges</td>
<td>Interstream Barging B.V.</td>
<td>Interstream Barging B.V.</td>
<td>Fixed</td>
<td>—</td>
</tr>
<tr>
<td>All tankers</td>
<td>Eastport Maritime</td>
<td>Eastport Maritime</td>
<td>Fixed, variable</td>
<td>—</td>
</tr>
<tr>
<td>IMrail</td>
<td>Den Hartogh Logistics N.V.</td>
<td>Den Hartogh Logistics N.V.</td>
<td>Fixed</td>
<td>—</td>
</tr>
<tr>
<td>LoadDum</td>
<td>Only 1 if $i$ and $j$ represent the same location</td>
<td>Negligible transport costs</td>
<td>Negligible transport costs</td>
<td>— —</td>
</tr>
</tbody>
</table>
Verification and Validation of the case study optimization model

K.1 Verification

- **Verification step 1: Identify and remove errors in the model**
  
  Code verification was performed by handling error messages until there were none left and by observing that the model in most scenarios comes up with the optimal mixed integer solution (no optimality gap) within a minute and for the more complex scenarios (e.g. when all regions are shifted to 4C4Com) comes up with a best solution having an optimality gap with the best LP bound of .02% within 10 minutes.

- **Verification step 2: Determine logic of results**
  
  We verified the total flows indeed add up to 1,189,140 tons in all scenarios. Zooming in on the results of the AsIs situation as an example, taking the flows originating from producer 1 (now necessarily on behalf of shipper 1), Table K.1 shows that 7,890 tons of 500 ppm styrene flows from [redacted] to customer 2 via a truck. Moreover, the capacity of a truck is 27 tons, requiring 293 trucks, as confirmed in Table K.2. Also, manual checking confirms truck is the cheapest possible modality here. Similar checks can be done for other flows. Naturally, when all demand is shifted to 4C4Com, all demand is supplied on behalf of shipper 5 (i.e. 4C4Com), though the product still physically originates from the 4 participants, albeit in an optimized way.

<table>
<thead>
<tr>
<th>Table K.1: Flows from producer 1 to customers 1 to 5 on behalf of shipper 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>k</strong></td>
</tr>
<tr>
<td><strong>co1</strong></td>
</tr>
<tr>
<td>8510</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table K.2: Number of vehicles corresponding to flows in Table K.1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>k</strong></td>
</tr>
<tr>
<td><strong>co1</strong></td>
</tr>
<tr>
<td>316</td>
</tr>
</tbody>
</table>
K.2 Validation

- **Validation step 1:** For those styrene consumers with whom Shell currently collaborates, compare true modalities on corresponding lanes with model modalities.

  The model seems to correctly choose modalities, as for 13 customers – out of the 15 customers we were able to check – the modalities chosen in the model and used in reality coincide, and for the other 2 customers the deviations can easily be explained. However, the deviations do not immediately imply improvement options for the AsIs situation (i.e., without collaboration) as cost differences are small and in some cases may deviate from true costs due to estimations. See Table K.3 for a complete and detailed overview of the first validation step.

- **Validation step 2:** Compare average transport costs per ton currently incurred by Shell with average transport costs per ton derived from the model.

  In the AsIs model situation, average transport costs per ton equal €26. The average transport costs of SCE B.V. over 2011 and 2012 [Shell Chemicals 2011, Shell Chemicals 2012] equal €[...]. Hence, a difference of [...]% can be observed. This difference might be due to three reasons. Firstly, transport costs used as input for the model are estimated rather than true costs.

  Secondly and more importantly, we have designed a strategic optimization model rather than an operational optimization model. Kiesmüller, de Kok, and Fransoo [2005], based on data they received from a multinational company that ships large volumes of containers by road and water across Europe, argued that faster response times of road transporters make it easier for the shipper to work with road transport than with slower transportation modes, since the latter requires looking further ahead. Indeed, transport by tanker, barge, RTC or blocktrain requires a certain manufacturing lead time so to speak. Kiesmüller et al. [2005] showed that companies may decide to transport a robust percentage of at most 30 percent of all flows via the more expensive fast mode (in this case truck) rather than the slow mode (if both are possible) because postponement of the transport decision may lead to a better cost performance, since updated information (e.g. on size of demand/net stock) is available.

  Thirdly, since SCE B.V. [...]% of its customers, we do not know whether we can extrapolate the corresponding average transport costs. Maybe average transport costs would be lower if we were able to take into account the transport costs incurred to get product to the other [...]% of SCE B.V.’s customers (currently incurred by these customers themselves).

  Due to these reasons and the fact modalities implied by the model and modalities truly used by SCE B.V. largely coincide, we lack proof to state SCE B.V. can already perform better in the AsIs situation (i.e., without collaboration).

  Based on these reasons and the sensitivity analysis we believe savings between the AsIs situation and the ToBe situation are also representative in an operational setting, as differences will apply to both situations.
## Table K.3: Validation of AsIs situation on SCE B.V.’s behalf

<table>
<thead>
<tr>
<th>White</th>
<th>no data available;</th>
<th>green</th>
<th>Model AsIs modality corresponds to true AsIs SCE B.V. modality,</th>
</tr>
</thead>
<tbody>
<tr>
<td>red</td>
<td>Model AsIs modality does not correspond to true AsIs Shell modality, remarks explain why.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Case study optimization model flows OD pairs

L.1 Legend

For meaning of abbreviations/indices: see Appendix J.

We define an additional set of Shippers, since running the model for each individual shipper (in this case the 4 producers and 4C4Com) has been automatized. We define \( sh_1 - sh_5 \), where \( sh_1 - sh_4 \) correspond to \( pr_1 - pr_4 \) respectively and \( sh_5 \) presents 4C4Com. Hence, read flows as destined to go to node \( j \) with physical product from node \( i \) (often a producer, sometimes a dummy or a storage node), on behalf of shipper \( sh \).

L.2 Flows in AsIs situation

Table L.1: Flows on arcs in AsIs situation
Table L.2: Number of vehicles on arcs in AsIs situation
L.3 Flows in 100% ToBe 4C4Com situation

Table L.3: Flows on arcs in 100% ToBe 4C4Com situation
Table L.4: Number of vehicles on arcs in 100% ToBe 4C4Com situation

Table L.5: Flows to Region 1 when only shifting Region 1 to 4C4Com

For flows to Regions 2,3,4,5,6 see Table L.1 (remain unchanged).

Table L.6: Number of vehicles to Region 1 when only shifting Region 1 to 4C4Com

For number of vehicles to Regions 2,3,4,5,6 see Table L.2 (remain unchanged).

Table L.7: Flows to Region 2 when only shifting Region 2 to 4C4Com

For flows to Regions 1,3,4,5,6 see Table L.1 (remain unchanged).

Table L.8: Number of vehicles to Region 2 when only shifting Region 2 to 4C4Com

For number of vehicles to Regions 1,3,4,5,6 see Table L.2 (remain unchanged).

Table L.9: Flows to Region 3 when only shifting Region 3 to 4C4Com

For flows to Region 1,2,4,5,6 see Table L.1 (remain unchanged). Note that all 100 ppm is supplied from LBI and BASF rather than from all 4 participants since otherwise several 100 ppm suppliers would need to supply more 100 ppm styrene then their total demand (100 ppm and 500 ppm) shifted to 4C4Com.

Table L.10: Number of vehicles to Region 3 when only shifting Region 3 to 4C4Com

For number of vehicles to Region 1,2,4,5,6 see Table L.2 (remain unchanged). Note that all 100 ppm is supplied from LBI and BASF rather than from all 4 participants since otherwise several 100 ppm suppliers would need to supply more 100 ppm styrene then their total demand (100 ppm and 500 ppm) shifted to 4C4Com.

Table L.11: Flows to Region 4 when only shifting Region 4 to 4C4Com

For flows to Region 1,2,3,5,6 see Table L.2 (remain unchanged).

Table L.12: Number of vehicles to Region 4 when only shifting Region 4 to 4C4Com

For number of vehicles to Region 1,2,3,5,6 see Table L.2 (remain unchanged).

Table L.13: Flows to Region 5 when only shifting Region 5 to 4C4Com

For flows to Region 1,2,3,4,6 see Table L.2 (remain unchanged).
Table L.14: Number of vehicles to Region 5 when only shifting Region 5 to 4C4Com

For flows to Region 1,2,3,4,6 see Table L.2 (remain unchanged).

Table L.15: Flows to Region 6 when only shifting Region 6 to 4C4Com

For flows to Region 1,2,3,4,5 see Table L.2 (remain unchanged). Flows according to all 100 ppm demand supplied by producer 3 and 4 (else flows actually worsen in this case).

Table L.16: Number of vehicles to Region 6 when only shifting Region 6 to 4C4Com

For number of vehicles to Region 1,2,3,4,5 see Table L.2 (remain unchanged). Flows according to all 100 ppm demand supplied by producer 3 and 4 (else flows actually worsen in this case).
Case study results per region

Table M.1: Total SC cost and CO2 savings per region

<table>
<thead>
<tr>
<th>Region included</th>
<th>Shipper</th>
<th>Total SC costs AsIs</th>
<th>Total SC costs for region shifted to 4C4Com</th>
<th>Total SC cost difference</th>
<th>Kg CO2 in AsIs</th>
<th>Kg CO2 for region shifted to 4C4Com</th>
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</thead>
<tbody>
<tr>
<td>Region 1</td>
<td>Shipper 1</td>
<td>€2,230,000</td>
<td>€6,236,000</td>
<td>4,180,000</td>
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<td>11,390,000</td>
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<td></td>
<td>Shipper 2</td>
<td>€1,652,000</td>
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<td>3,274,000</td>
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<td>Shipper 3</td>
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<td>3,095,000</td>
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<tr>
<td></td>
<td>Shipper 4</td>
<td>€1,649,000</td>
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<td>3,095,000</td>
<td></td>
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<tr>
<td></td>
<td>Shipper 5</td>
<td>€6,236,000</td>
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</tr>
<tr>
<td>Total</td>
<td>Shipper 1</td>
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<td>€80,000</td>
<td>4,699,000</td>
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<td>242,000</td>
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Optimality gap .02%

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