Cross-chain collaboration in logistics: looking back and ahead

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The only thing special about the chemical elements that make you, is that they make you. That is the miracle of life. - Bill Bryson

Contents

1 INTRODUCTION

1.1 SYNTHESIS STUDY ON HORIZONTAL COLLABORATION AND 4C

Transport is fundamental to our economy and society. This is especially so for the open economy of the Netherlands, which is heavily depending on international trade. CBS (2019) calculates that in 2017 export accounted for 34% (or roughly 250 billion euro's) of the Dutch GDP. 61% of this is created by the export of physical goods produced in the Netherlands (119 billion euro's) and re-exports (33 billion euro's).

So, logistics is a big deal. And at the same time, it is a challenging industry. Profit margins are usually thin, roads are more and more congested, long-distance intermodal transport is difficult because of the different infrastructures in European countries, and the logistics workforce is decreasing. Therefore, the Dutch government and the logistics industry are keen to keep logistics profitable in the long run, by stimulating relevant applied academic research and innovative business models that reduce inefficiency in transport and logistics and strengthen the position of the Dutch logistics industry in the years to come.

A prominent topic in logistics innovation is horizontal collaboration. To remain competitive in the long run, logistics companies have an incentive to form horizontal collaborations that pool their capacities and as such increase their overall efficiency (Cruijssen et al. 2007, Gansterer and Hartl, 2018). To study and promote horizontal collaboration, the Dutch government has launched a support program in 2010 that is called *Cross Chain Control Centers* (or: 4C). This program has run for about ten years and will now transition into a new program that is more directly oriented to the societal goal of a sustainable economy, instead of the industry-focused approach of improving logistics functions in the Netherlands. After a decade of investment in research and commercial initiatives in the area of 4C, it is time to look back on the program, both its achievements and the areas where the program did not deliver what was expected.

This report has four main goals:

- To provide an overview of the main results, insights, and other accomplishments in the (academic) field of horizontal collaboration.
- To give recommendations to governments, commercial companies, and academia on how to proceed with horizontal logistics collaboration in the years to come.
- To use 4C project results to enrich existing horizontal collaboration typologies.
- To zoom in on the Netherlands as a case-study of intense public-private partnerships to develop 4C as a mature logistics value proposition. We will provide an overview of the accomplishments in government supported Dutch 4C projects and will give a critical reflection of why some more ambitious and structural solutions have not found solid ground yet.

Given these goals, the expected main audience for this synthesis report consists of the academic community and policy makers. We will now proceed with providing some relevant background to this 4C synthesis report.

1.2 BACKGROUND

The website of the Dutch top-sector logistics[1] introduces the concept of Cross Chain Control Centers (4C) as follows:

> *"4Cs are control centers where the most recent techniques, advanced software concepts and supply chain professionals come together. In a 4C, information flows are coupled to flows of physical goods in an innovative way. By exchanging this information between various entities, a 4C makes it possible to orchestrate across multiple supply chains. This increases the scale of jointly controlled transport flows, which makes it possible to use rail and waterways as alternatives for road transport. In addition, the load factors of trucks may increase, leading to not only cost reductions, but also to improved accessibility of cities and a more sustainable management of physical flows. The realization of a 4C ensures an improved overview, better alignment and bundling of activities, reduction of supply chain costs through load consolidation, a smaller environmental footprint, the creation of more jobs, and new knowledge that can also be applied in other industry sectors. 4C therefore is the next revolutionary step in supply chain management (SCM). The importance of 4C is to enable coordinated decision making in complex European or global supply chains across multiple organizations and industries. A 4C can be realized in a single sector, but also across industries. Key is that the respective supply chains show enough similarities and synergy to joint orchestration through a 4C possible."*

This introduction or extensive definition of a 4C makes it clear that expectations are high. As we will see further in this report, collaboration between multiple supply chains may significantly improve efficiency. Successful cases have shown that collaboration or joint orchestration can reduce transport cost and distance travelled, lower CO_2 emissions, enable modal shift, reduce capacity shortages, act a catalyst for joint innovation, etc. All this makes that there is a broad desire for more intense logistics collaboration. However, building and maintaining successful 4C proves to be difficult in practice. We will discuss the opportunities and impediments for 4C and horizontal collaboration in detail in chapters 6 and 7.

The Dutch 4C program has financially supported over70 projects, both academic and practice oriented. In addition to the (yearly) measurement of quantitative KPI improvements brought about by these projects, this synthesis study provides a critical reflection in words of the results of these projects. This will give valuable input to policy makers deciding on how to proceed with the topic of 4C and horizontal logistics collaboration. Follow-up programs will focus more on energy transition and sustainability and given the promise of 4C that it can reduce emissions by making the transport sector more efficient, 4C will likely remain of interest in the years to come.

In this synthesis report we will also review empirical studies of 4C and the related topic of horizontal collaboration. This will map the experiences, good and bad, of 4C-like logistics collaborations. This part also provides valuable information to policy makers. Is the time right to leave cross-chain collaboration to the market? Or should governments still participate or incentivize? The ten years of experience with 4C in the Netherlands and beyond should give ample evidence to answer this question.

We will now continue with a 10-year step back in time, to the year 2010, when the 4C program took off.

[1] https://top-sectorlogistiek.nl/cross-chain-control-centers/

1.2.1 Situation around 2010

To understand where the idea of a 4C originated, it is worthwhile to look at the perceived threats and opportunities for the logistics industry in 2010. Topteam Logistiek (2011) wrote a report describing the state of the Dutch logistics industry and defined several concrete ambitions.

Firstly, there were several clear challenges, or even threats. Firstly, in the period 2003-2010 the port of Rotterdam dropped from rank 3 to rank 11 globally in terms of TEU throughput, being overtaken mostly by fast-growing Chinese ports[2]. Also, on the global Logistics Performance Index (LPI) the Netherlands went down from rank 2 in 2007 to rank 4 in 2009[3]. Then, the strengthening position of China on the world stage was dramatically changing global transport flows in which the Netherlands was a longtime important player. Fourth, there was the centralization wave of European Distribution Centers (DCs), with the risk that the Netherlands would lose some DC activities of multinationals. And finally, the trend towards more customer-specific production and deliveries was transforming the logistics industry.

Next to these threats, there were also several clear opportunities from these dynamics in the logistics industry. First and foremost, the Netherlands is still very well positioned geographically to be the 'gateway to Europe', as the Port of Rotterdam slogan says. In addition to that there is the digitization of logistics processes, which makes it possible to orchestrate logistics flows that take place outside the Dutch borders. This opportunity is strengthened by the high-level customs expertise in the Netherlands. The digitization of the Dutch logistics industry is also shown by the fact that already in 2010, 90% of the bigger transport companies in the Netherlands were using Transport Management Software (TMS) and were therefore able to easier optimize and combine transport flows. In many cases these TMS's were integrated in the companies' Enterprise Resource Planning (ERP) systems. The Netherlands was also an early adopter of RFID, Wi-Fi, GPS, and mobile internet in logistics applications, which strongly enables real-time management and orchestration of transport flows. Many of these applications were developed by Dutch software companies, which also provided digital services such as spend and tender management, cargo portals, transport marketplaces, trade compliance accounting, etc.

Taking in these opportunities and threats, Topteam Logistiek (2011) listed five very concrete goals for the year 2020[4]:

1. The Netherlands are the European leader in the global LPI.
2. The Netherlands earn at least € 10 billion from supply chain orchestration services.
3. The number of companies that opens logistics facilities in the Netherlands grows by 30%.
4. The load factor of trucks grows from 45% to 65%.
5. Logistics has 50% more higher-education jobs.

One of the prominent strategies that were developed for reach goal number 4 was to incentivize bundling of logistics flows across supply chains. This idea was still quite new at the time, although the Netherlands

[2] Note that this development indeed has stopped. Rotterdam is still in 11th place in 2019 (http://www.worldshipping.org/about-the-industry/global-trade/top-50-world-container-ports)

[3] The Netherlands was in 6th place in the most recent ranking of 2018, after Germany, Sweden, Belgium, Austria and Japan (https://lpi.worldbank.org/international/global)

[4] This will be elaborated on in Section 8.2

were already taking quite a few steps in this direction. For example, Raad voor Verkeer en Waterstaat (2003) mentions the 'Logistics Datahub Netherlands[5]' initiative by the company Informore that aimed at gathering real-time logistics data from many shippers and Logistics Service Providers (LSPs) to find bundling possibilities. On the academic side, at Tilburg University the first literature review specific for horizontal collaboration in transport and logistics was published (Cruijssen et al., 2007).

Van Laarhoven (2008) in a strategic advice for the Dutch government coined the term Cross Chain Control Centers (or: 4Cs), which combined a number of logistics developments into a collaboration concept that answered to a number of challenges in the logistics sector and also leveraged on the Dutch logistics strengths described above. Developing 4Cs become a part of a significant investment program that started in 2012 where the Dutch government chose a hybrid strategy between active intervention (incentives, regulation, taxing) and self-organization by the industry.

1.2.2 The birth of 4C: Supply chain control and collaboration as a conscious strategy

Van Laarhoven (2008) found that there were many opportunities for the Netherlands in the area of chain orchestration and logistics configuration. The ambition was to lead the Netherlands to the position of market leader for European logistics orchestration functions in 2020. The concept of 4C was the materialization of this ambition and was defined as *the joint logistics orchestration of many big shippers across multiple supply chains.* The idea of a 4C was that by coordinating and orchestrating multiple supply chains together by means of the best technology and experts, efficiency gains and new services would arise. An innovation program by the government was launched to further develop the concept through research and commercial pilots.

Looking back at this birth of the concept of 4C, it is striking that even in the definition the proposition is focused on big (international) shippers. As the program developed in the years 2010-2020, this emphasis shifted to include and even focus on LSPs and SME shippers. This now seems logical, since SMEs have less scale than their multinational colleagues, and therefore usually have more to gain by bundling flows with other companies. Most of the 4C pilot projects have indeed focused on SMEs. Hence, the observation here is that the scope of the 4C program has broadened over the years from specific 'big shippers' to all operational stakeholders in the supply chain. The logic in that is that the realization of ambitions set, in many cases required the close involvement of LSPs and SME shippers.

From an ICT perspective, van Laarhoven (2008) notes that the rapid development of international supply chains would not have been possible without the rise of new ICT systems. The development of international ICT networks, ERP systems, 'transparency layers' and specific supply chain automation solutions will make it possible to better control and orchestrate supply chain complexities. With the help supply chain transparency software companies can automatically check where in the supply chain components are, assess current and project inventory levels, and decide which transport movement are needed to bring them to the correct location for assembly. The rise of these ICT systems makes collaborative management of multiple supply chains in complex environments possible, thereby enabling the development of 4Cs.

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[5] Logistieke Datahub Nederland in Dutch.

These insights from the situation of the logistics industry in 2010 made that the Dutch government decided to invest in the development of logistics controls towers and make it part of their strategic innovation agenda for the logistics industry. As we will see later in this document, by 2010 some early initiatives for 4Cs were already in place.

1.2.3 Meanwhile in Europe

Not only in the Netherlands, but across Europe thought leaders and policy makers concluded that increased collaboration in the logistics industry was called for. Before 2010, EU funded research mostly focused on technical innovations in transport infrastructure, vehicles, and ICT systems. An overarching supply chain view was missing and therefore was only indirectly included in the European Union research agenda. As a result, it was difficult for disruptive logistics innovations that potentially span the entire supply chain from raw materials to the end consumer, such as control towers, vertical and horizontal collaboration, to get financial support from European innovation funds. This changed with the launch of the FP7 research and innovation program, in which a few clear supply chain calls were included. Later, the supply chain industry finally got a strong foothold in Brussels with the recognition of ALICE (acronym for: *Alliance for Logistics Innovation through Collaboration in Europe*) as a formal European Technology Platform in 2013.

(ETPs) are industry-led stakeholder fora that develop short to long-term research and innovation agendas and roadmaps for action at EU and national level to be supported by both private and public funding. ETPs are a key element in the European innovation ecosystem and will help foster innovation in the EU and will help to 1) develop strategies and provide a coherent business-focused analysis of research and innovation bottlenecks and opportunities related to societal challenges and industrial leadership actions, 2) mobilize industry and other stakeholders within the EU to work in partnership and deliver on agreed priorities, and 3) share information and enable knowledge transfer to a wide range of stakeholders across the EU.

ALICE (2016) has identified five different areas that need to be specifically analyzed and addressed in terms of future research and innovation needs. These areas are:

1. Sustainable, Safe and Secure Supply Chains
2. Corridors, Hubs and Synchromodality
3. Information Systems for Interconnected Logistics
4. Global Supply Network Coordination and Collaboration
5. Urban Logistics

Since 2016, these five research areas have been taken up by separate working groups. Working group 4 on Global Supply Network Coordination and Collaboration is the group that studies 4Cs and horizontal collaboration in transport and logistics and its main research topics are represented in the ALICE agenda in Figure 1. As can be seen form the figure, horizontal collaboration is the first topic to be taken up on the road towards the final goal of zero emission logistics in 2050.

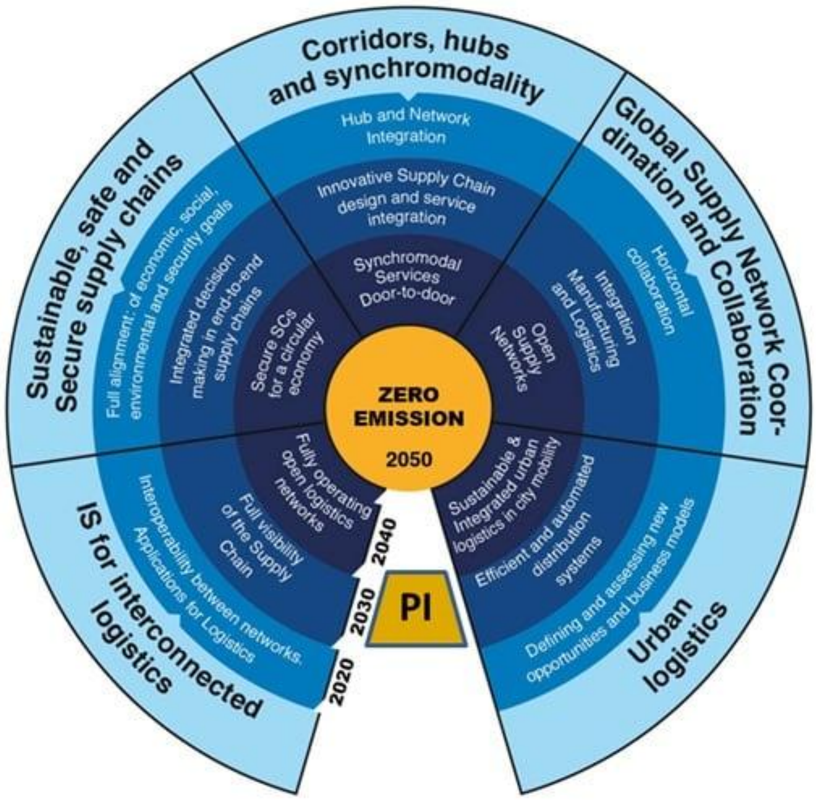

Figure 1. ALICE roadmap

ALICE (2015) explains that the mission statement of the global supply network coordination and collaboration working group is to develop supply networks that are operated as a whole, meaning with full vertical and horizontal coordination and collaboration. Coordination and collaboration here concern the full scope of supply chain operations from sales planning and order management, logistics and transport planning to strategic network design. The goal is to identify and define research and innovation challenges to achieve the following vision: 'a breakthrough in EU logistic efficiencies via removing possible barriers through new concepts and approaches, for closer vertical and horizontal collaboration among different network owners in Europe'. This will create a smooth transition from independent supply chains to open global supply networks. To make the most efficient use of available resources and modes, they must be compatible, accessible, and easily interconnected.

As is clear from this mission statement, this ALICE working group is very much connected to the Dutch topic of Cross Chain Control Centers. Network coordination and 4C are different ways to refer to a similar ambition, which is to arrive at a far more efficient and clean transport and logistics industry by structural and seamless collaboration between many logistics operators across many supply chains. Next to these two terms, there are more terms arising in the logistics literature that also refer to this same ambition. In Section 5.1 we will give an overview of the terminology encountered in literature and practice, but it is good to mention here already that the term 4C has not been widely taken up outside the Netherlands. Therefore, in the remainder of this report, we will also use other terminology than 4C when this is more intricately linked to the discussed literature or case study under consideration.

1.3 Outline of the Report

This report is further organized as follows. In chapters 2 and 3 some major logistics developments are discussed in general and with a specific focus on horizontal collaboration. Then, in Chapter 4 we compare the adoption of collaboration and innovation in the logistics industry with other sectors. The next three chapters provide an overview of the relevant literature around 4C and horizontal collaboration in logistics. Next to a meta-review of existing literature studies (Chapter 5), we pay special attention to collaboration typologies (Chapter 6) and empirical research on the achieved and potential benefits of collaboration and its perceived or encountered impediments (Chapter 7). In Chapter 8 we discuss the case study of the Netherlands, and in Chapter 9 we summarize the lessons learned in this report by discussing a number of hypotheses on 4C. In the final chapter we formulate the main conclusions and recommendations for business, academia, and policy makers.

2 BROAD DEVELOPMENTS IMPACTING SUPPLY CHAIN COLLABORATION

Supply chain collaboration is not a topic that is relevant in isolation. It is impacted by some larger global developments that change the logistics industry. In this chapter we discuss four major developments that impact supply chains and call for collaborative approaches: 1) Sustainability, 2) Digitization, 3) Increased optimization power and 4) Globalization.

2.1 SUSTAINABILITY

Following the alarming reports of the International Panel of Climate Change (IPCC), most of the world leaders now are taking actions to significantly reduce greenhouse gas emissions and to ensure a livable planet also in the second half of the 21st century and onwards. Several climate conferences have been organized by the United Nations, with a provisional highlight written down in the Paris Agreement of 2016. As a short summary, the undersigning countries[6] vow to do everything in their ability to limit the average global temperature rise by 1.5-2 degrees Celsius.

The European Union is one of the main promoters of the Paris Agreement. As the EU website[7] states:

> *"The EU has the most comprehensive and ambitious legislative framework on climate action in place and it is successfully transitioning towards a low emissions economy, aiming at climate neutrality by 2050 – between 1990 and 2017 its greenhouse gas emissions were reduced by 23% while the economy grew by 58%. The EU has already overachieved its 2020 greenhouse gas emissions reduction target and has completed its unique binding legislative framework that will allow us to over-deliver on our climate targets for 2030. At the same time, the EU Adaptation Strategy has encouraged national, regional, and local adaptation action since 2013. Conscious that our emissions make up only around 9% of the global total, the EU is continuing its outreach and collaboration, financial and technical, to all partner countries. The EU remains the world's leading donor of development assistance and the world's biggest climate finance donor. Providing over 40% of the world's public climate finance, the EU and its Member States' contributions have more than doubled since 2013, exceeding EUR 20 billion annually."*

It almost goes without saying that sustainability has become the most important driver for transport efficiency. In Section 7.1 we will discuss in more detail the available empirical research on the motivations that companies have for engaging in collaboration, but it is fair to say that recently the importance of sustainability in this decision has become more and more prominent and that will only become more apparent in the years to come.

[6] All countries in the world except for four OPEC countries (Iran, Iraq, Angola and Libya), two countries torn by conflicts (South Sudan and Yemen). Sadly, the United States joined this list by withdrawing from the accord in 2019.
[7] https://ec.europa.eu/commission/presscorner/detail/en/IP_19_5534)

The transport industry is considered a growing contributor to global climate change. According to the International Transport Forum (ITF) freight transport accounts for about 39% of transport CO_2 emissions and around 8% of CO_2 emissions worldwide. It is also a major contributor to air pollution. Road constitutes 62% (50% non-urban, 12% urban) of emissions, while sea contributes 27%, air 6%, rail 3% and inland waterways 2%. In Europe, freight constitutes 6% of total CO_2 emissions and 30% of transport CO_2 emissions. As it stands, the total emissions from freight need to be almost fully decarbonized by 2050 compared to the 2015 levels if we are to meet the climate ambitions set out in the Paris Agreement. However, the real challenge facing us is that demand for freight transport is predicted to triple and associated CO_2 emissions to more than double over the same period, according to the ITF. This means that nothing short of a transformational shift towards the decarbonization of global freight transport is necessary to meet global climate targets (ALICE, 2019).

Given the massive task, it is good to see that following up on the Paris Agreement of 2016, more and more governments, associations, and businesses are setting bold climate targets. The ambition is for Europe to be the first climate-neutral continent in the world by 2050[8]. This will be achieved with a two-step approach, designed to reduce CO_2 emissions by 50%, if not 55%, by no later than 2030. In addition, more than 600 companies have committed to these targets, with some even pledging to reach zero emissions by 2050. The deployment of greener and cleaner vehicles, trains, barges, ships, and airplanes as well as other technologies for a more efficient transport network is forecasted to be too slow to reach our climate change targets. The short-term focus therefore is on finding new opportunities for efficiency gains in freight transport and logistics.

In this section we explain that CO_2 emissions can not only be reduced by technological advances (lower fuel consumption, electrification, etc.), but that also significant savings can be achieved through innovative supply chain concepts such as collaboration. Large efficiency gains and benefits to all logistics stakeholders are possible by doing more with less. The existing idle capacity of assets and infrastructure in all modes of transport could be better used, and flows could be managed in a more integrated way. Open logistics services and connecting networks can improve capacity utilization. It is difficult to see how we can reduce transport emissions in the short run without increased supply chain collaboration. In other words: *Given the eminent threat of global warming, transport inefficiency is a luxury that belongs to the past*

Fortunately, there is a quickly developing body of research that is available to logistics decision makers to reduce the carbon footprint of their logistics operations. A comprehensive review of the literature on 'green SCM' is offered by Tseng et al. (2019). the study finds a consistent growth in the evaluation of green SCM practices and performance. Although the concept of green SCM already started gaining popularity among academicians from the beginning of the 20th century, they find a sharp growth of publications on the topic after 2010, resulting in a body of literature of at least 880 papers until September 2010 when their paper was submitted for publication.

[8] The new president of the European Commission, Ursula von der Leyen said in her first statement to the European Parliament plenary session: "I want Europe to become the first climate-neutral continent in the world by 2050. To make this happen, we must take bold steps together. Our current goal of reducing our emissions by 40% by 2030 is not enough. We must go further. We must strive for more. A two-step approach is needed to reduce CO_2 emissions by 2030 by 50, if not 55%".

Another overview is provided by McKinnon (2018). He shows that there is no shortage of strategies or carbon-reducing initiatives. Policymakers and business leaders who are committed to bringing emissions down to levels consistent with the COP21 Paris Climate Change Agreement can use it to come up with regulation, design programs and action plans. In addition, ALICE (2019) provides some detailed actions that can be taken by the industry to reduce overall emissions. Some of them relate to supply chain collaboration and these are summarized in Table 1.

Measure	Description	Link to collaboration
Adjust truck size to load	The fuller the load compartment the better the overall efficiency. Matching the size of the vehicle with the load (volume or weight) contributes to efficiency.	By combining LTL shipments of various shippers or LSPs trucks can be filled to (almost) their exact capacity.
Optimizing use of vehicle space	Optimize the loading of vehicles taking the vehicle and freight dimensions into account. Improvements of the load factor of the vehicle through efficient unit loads and a combination of mechanical and manual loading may be necessary.	Combining loads from shippers from various supply chains makes it possible to better use the multidimensional capacity of trucks, by for example combining heavy with voluminous products in a truck.
Bundling shipments across product categories with similar shipment characteristics	This can be realized through 1) horizontal collaboration, 2) freight exchange platforms, 3) open cross docks, 4) mixed load and weight volume, 5) urban consolidation centers, 6) crowd shipping, 7) high capacity vehicles, 8) use of public transport modes	On the short term, these bundling measures are only[9] possible if they are somehow coordinated through a control center such as a 4C.
Modular packaging	Redesign of product packaging and load carriers for optimal fit to products.	Modular packaging (see also Section 3.1) strongly facilitates horizontal collaboration as loads can be better combined physically.
Backhauling	Picking up or delivering cargo on return or round trips as compared to returning with empty vehicles or vessels.	To increase backhauling and reduce empty repositioning it is important to oversee as many supply chains and movements as possible. A 4C or other forms of horizontal collaboration strongly increases the possibility of finding backhauls.
Open warehouses	This solution looks for a systemic load consolidation and optimization in which the capacity in logistics sites and transport networks are made available	Multi-supplier or multi-retailer warehouses have an important effect that either starting points or destinations of multiple transport

[9] Note that once a Physical Internet (see Section 3.7) is in place, these bundling measures can occur decentrally, so without an overarching control tower. In a way, the Physical Internet is then an automation of a 4C.

	for use in an optimized way for multi-supplier and multi-retailer groups.	are the same. This is especially profitable if the warehouses host companies from the same industry.

Table 1. Link between collaboration and proposed sustainability measures (ALICE, 2019)

In the Netherlands, following up on the COP21 in Paris and realizing the massive task it meant for the Dutch logistics industry, a work program was started called 'Factor 6'. By 2050, the Netherlands must have reduced its greenhouse gas emissions by 60% compared to the 1990 base year. Since 1990, the Dutch economy obviously has grown significantly, resulting in an increase of 150% in the demand for transport. Ceteris paribus that means more transport movement and more CO_2 emissions by a factor of 2.5. In addition, the agreed 60% reduction in absolute emission levels, requires another reduction by a factor 2.5. Together, this challenge is summarized as Factor 6: to reach the COP21 goals, the logistics industry must improve its efficiency by roughly a factor 6.

This can be achieved in three high-level ways:

1. Reduce emission per ton-km (Cleaner vehicles, modal shift, driver trainings, etc.)
2. Reduce the number of transported tons (by producing smaller products, reducing packaging, 3D printing etc.)
3. Reduce the number of kilometers travelled (local sourcing, load factor optimization, improved network design, collaboration, Etc.

To achieve Factor 6, most likely all three approaches must be followed in parallel. In this document, we focus on the third approach.

It is estimated that in Europe vehicles are empty 25% of the time that they are moving (Eurostat, 2019). In this regard, sharing available and idle capacity is key to overcome the increase in freight transport fragmentation with smaller but much more frequent shipments (due to e-commerce for example, see Section 3.5). A significant reduction in empty running (for which algorithmic freight-matching engines are available) could reduce empty running by 15-40% overall. Horizontal collaboration or coordination through a 4C seems a prerequisite to accomplish any of this.

In a European stakeholder consultation, ALICE (2019) arrived at the following ranking for transport measures to fulfill the Paris agreement decarbonization strategy (based on both impact and feasibility):

1. Renewable energy in combination with electrification, hybrids, and hydrogen
2. Multimodal optimization
3. Load consolidation and optimization
4. Use of efficient vehicles, vessels, and fleets
5. Synchromodality and flows synchronization
6. Improve fleet operation
7. Supply chain restructuring
8. Consumer behavior

At least three measures (number 2, 3, and 5) will be difficult to achieve without coordination, which highlights the importance of 4Cs to decarbonize transport.

Sustainability was also one of the motivations for Van Laarhoven (2008) to propose the 4C concept. This is because cross-chain control aims at more efficient coordination of production and orchestration of physical movement of goods. This should automatically lead to fewer negative environmental impacts from so-called 'supply chain waste'. Improved coordination of transport modes leads to reduced empty running and as a result also to smaller CO_2 and NO_x emissions.

Supply chain waste is also referred to as the 'hidden costs of transport'. Van Breedam and Vannieuwenhuyse (2016) argue that without strongly improved coordination of transport, the share of hidden costs in the total logistics cost is likely to increase much faster than the actual direct cost for logistics as is illustrated in Figure 2.

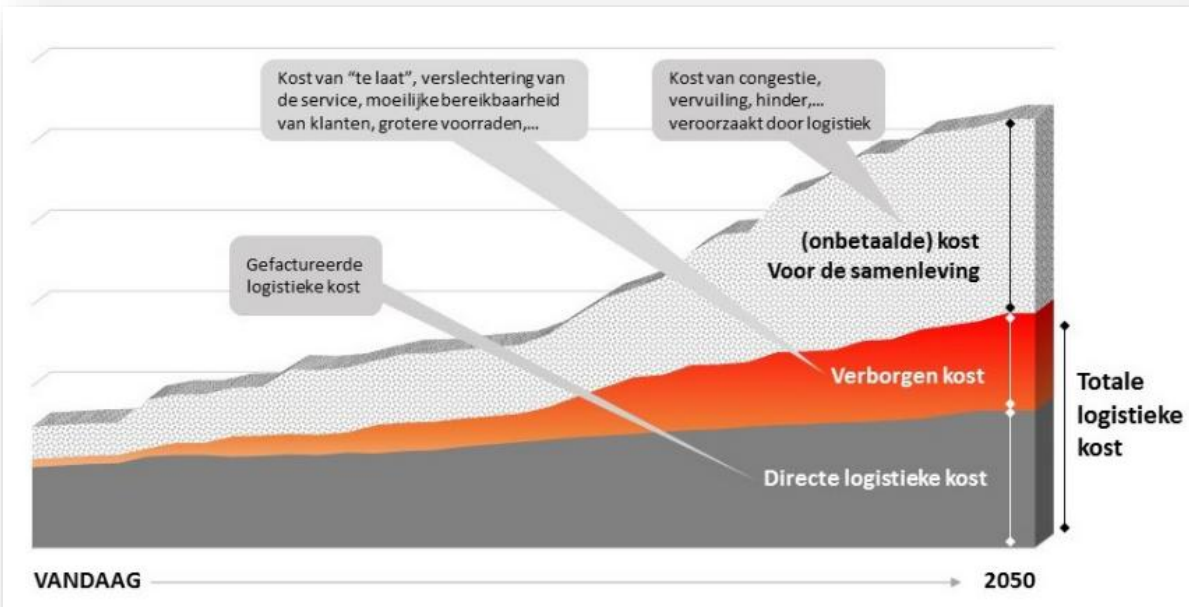

Figure 2. Ceteris paribus development of logistics cost (Van Breedam and Vannieuwenhuyse, 2016) [In Dutch]

Ferrell et al. (2019) adds to this that transport inefficiency is harmful as obviously it brings no added value to society or consumers and because of the contribution that freight movement has on the growth of CO_2 emissions. Even if we accept that fossil fuel combustion will be the predominate propulsion mechanism to move freight for the foreseeable future, the amount of CO_2 associated with empty miles to reposition assets is problematic at best and approaching being unacceptable to some. In the United States transport generates about 29% of CO_2 emissions with the freight transport sector alone (which is defined as trucks, ships, and trains used to deliver freight), contributing approximately 10% of the CO_2 emissions annually (USEPA, 2019). Simply reducing unproductive trips by means of a 4C can make an important difference.

2.2 Digitization

In its essence, digitization means transforming analog information into zeroes and ones so that computers can work with it. There are many examples of digitization in businesses. Converting handwritten or typewritten text into digital form is an example of digitization, which for example still applies today to some shipping documents.

Digitization is a prerequisite for logistics control towers of any considerable size. Fortunately, digitization has been developing at a fast pace over the last couple of years, taking away a huge impediment for the dynamic coordination of multiple supply chains from a single physical (or virtual) location.

This digital transformation has received enormous attention in recent years. There are many recommendable books on the topic, but a good overview is given by Raskino and Waller (2015). For the purpose of this report, we limit ourselves to only a few subtopics of digitization that are of specials relevance to 4Cs: 1) Big data analytics, 2) Industry 4.0 and the internet of things, and 3) Robotics and artificial intelligence.

2.2.1 Big data analytics

A serious amount data is available. Until 2010 most of the digital data available was (more or less) structured company data from dedicated systems for the management certain company processes. The steep growth that can be seen from Figure 3 is primarily caused by the rise of social media that generate enormous amounts of data every second. And in principle these data can be used for better decision making. This is called *big data analytics*.

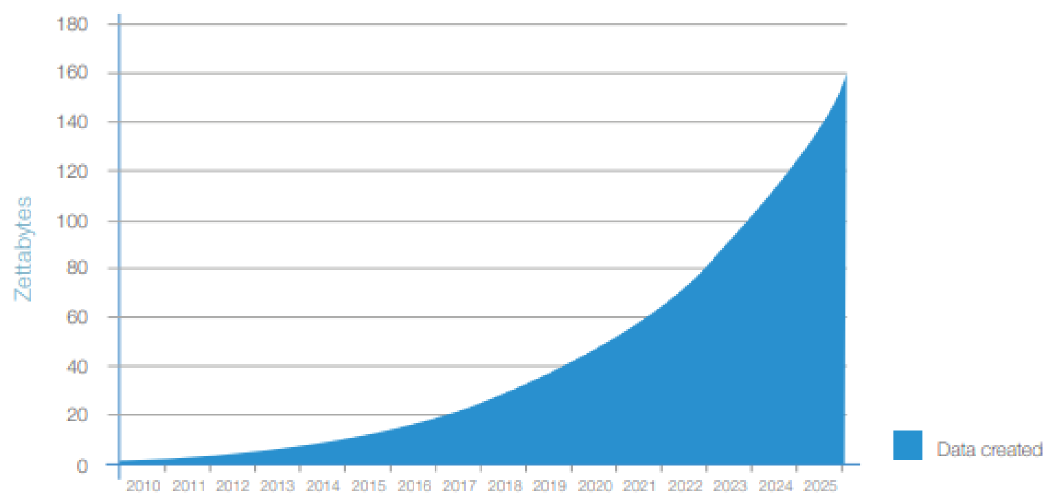

Figure 3. Annual size of the global datasphere (Source: IDC's Data Age 2025 study, April 2017)

In recent years, also the amount of data produced from end-to-end SCM practices has increased exponentially. And often supply chain professionals are struggling to handle these huge datasets. Supply chain analysts are using new techniques to investigate how data are produced, captured, organized, and analyzed to give valuable insights to industries.

Tiwari et al. (2018) investigate big data analytics research and applications in SCM between 2010 and 2016. They define big data as huge or complex sets of data, that consist of Exabytes and more. See Figure 4 to interpret the size of an exabyte.

yotta	[Y]	10^{24}	=	1 000 000 000 000 000 000 000 000
zetta	[Z]	10^{21}	=	1 000 000 000 000 000 000 000
exa	[E]	10^{18}	=	1 000 000 000 000 000 000
peta	[P]	10^{15}	=	1 000 000 000 000 000
tera	[T]	10^{12}	=	1 000 000 000 000
giga	[G]	10^{9}	=	1 000 000 000
mega	[M]	10^{6}	=	1 000 000
kilo	[k]	10^{3}	=	1 000
hecto	[h]	10^{2}	=	100
deca	[da]	10^{1}	=	10

Figure 4. Digital information metrics

With big data analytics it is not possible anymore to store all available data locally and process, interpret, and visualize it. The size of the global datasphere is increasing exponentially (see Figure 3) and this is predicted to continue to do so in the next couple of years. Academia and practitioners agree that this flood of data creates ample new opportunities, therefore many organizations try to develop and enhance their big data analytics capability. The topic of big data is continuously evolving and expanding, and the main attributes of big data are now captured in into the *5V concept*, which refers to volume, velocity, variety, verification/veracity, and value. Zhong et al. (2016) provide a comprehensive discussion on the current big data technologies including storage, data processing, and data visualization technology. They reviewed more than 100 recent publications on big data applications in SCM and were able to categorize them into the following topics:

1. Strategic sourcing
2. Supply chain network design
3. Product design and development
4. Demand planning
5. Procurement
6. Production
7. Inventory
8. Logistics and distribution
9. Supply chain agility and sustainability

Tiwari et al. (2018) define the term *big data analytics* as the application of advanced analytic techniques including data mining, statistical analysis, predictive analytics, etc. on big datasets. It refers to the processes of examining and analyzing huge amounts of usually unstructured data to draw conclusions by uncovering hidden patterns and correlations, trends, and other business valuable information and knowledge, to increase business benefits, increase operational efficiency, and explore new market and opportunities. Figure 5 shows the big data analytics model by Mayo (2017)

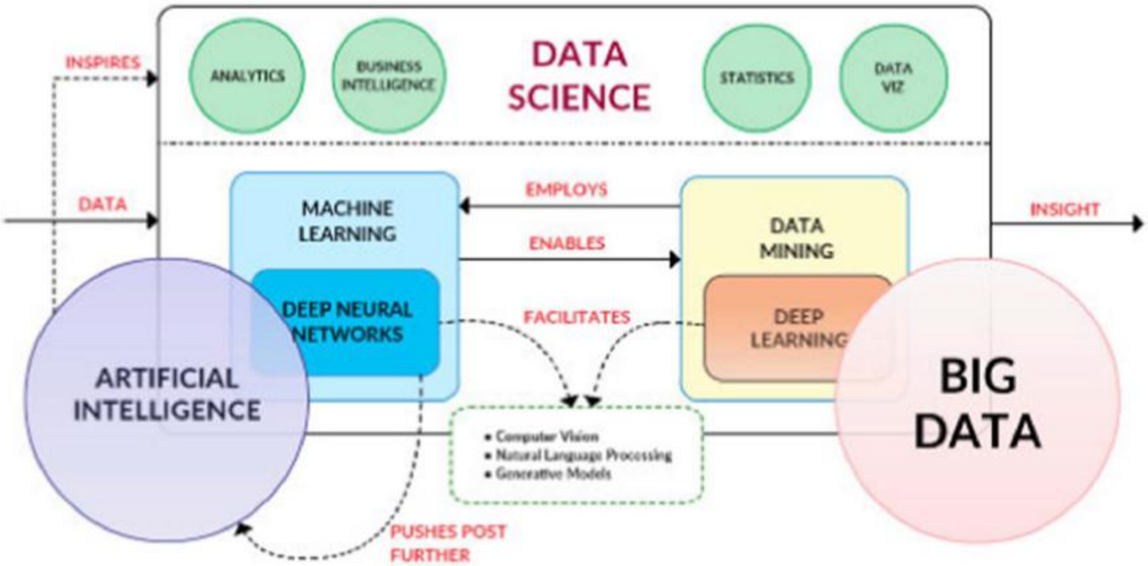

Figure 5. Big data analytics model (Mayo, 2017)

Nguyen et al. (2018) have produced another review of recent research in the field of big data analytics. This review explains where and how big data analytics has been applied within the SCM context. It addresses four specific research questions: (1) in what areas of SCM is BDA being applied? (2) At what level of analytics is BDA used in these SCM areas? (3) What types of BDA models are used in SCM? (4) What BDA techniques are employed to develop these models?

2.2.2 Industry 4.0 and the internet of things

Erboz (2017) introduces Industry 4.0 by listing some examples of the diverse technologies that belong to Industry 4.0:

- Mobile devices
- Internet of Things (IoT) platforms
- Location detection technologies
- Advanced human-machine interfaces
- Authentication and fraud detection
- 3D printing
- Smart sensors
- Big data analytics and advanced algorithms
- Multilevel customer interaction and customer profiling
- Augmented reality/ wearables
- Fog, Edge, and Cloud computing
- Data visualization and triggered ‘real-time’ training

Most of these technologies can be summarized into four major components:

- Cyber-physical systems

- Internet of Things
- Cloud computing
- Cognitive computing

For the purpose of this report, and for SCM at large, the development referred to as the *internet of things* (IoT) is the most relevant component of Industry 4.0. Ben-Daya et al. (2019) have reviewed the logistics literature on the IoT. They define IoT in the context of SCM as follows:

'*The Internet of Things is a network of physical objects that are digitally connected to sense, monitor and interact within a company and between the company and its supply chain enabling agility, visibility, tracking and information sharing to facilitate timely planning, control and coordination of the supply chain processes.'*

The IoT takes supply chain communications to another level: the possibility of human to things communication ('Hey Google…') and autonomous communication among things while being stored in a facility or being transported between different supply chain entities. These new capabilities offer exciting opportunities to deal more effectively with SCM challenges through improved visibility, agility, and adaptability (Ellis et al., 2015). The data emitted by smart objects, when effectively collected, analyzed, and turned into useful information, can offer unprecedented visibility into all aspects of the supply chain, providing early warnings of situations that require remediation. Responding to these signals in time can create new levels of supply chain efficiency. What was lacking so far is not the availability of information but rather the technologies for collecting and processing big data and the time lag between data collection and action. IoT will allow the reduction in the time between data capture and decision-making that enables supply chains to react to changes in real time (Ellis et al., 2015).

Furthermore, according to Ferrell et al. (2019) IoT supports operational efficiency by providing information about networks and asset utilization. IoT can connect different parts of a supply chain, and thus can provide large amounts of information and data to facilitate detailed analysis. IoT can also be beneficial in last-mile delivery, which causes challenges for the logistics provider as consumer demands become more sophisticated and the number of delivery points continue to grow. IoT can connect the logistics provider with the end consumer by cost-effective solutions that provide value for the end customer and operational efficiency for the logistics provider. It can also help the LSPs with asset tracking, which gives companies a way to make better decisions and save time and money. Together, these benefits can also have the potential to facilitate horizontal collaboration through 4C concepts.

IoT will also enable remote management of supply chain operations, better coordination with partners and can provide more accurate information for more effective decision-making, thereby strongly enabling 4C concepts.

2.2.3 Robotics and artificial intelligence

The Oxford Dictionary defines Artificial Intelligence (AI) as *the theory and development of computer systems that are able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages*. AI applications are appearing extremely fast and are expected to become ubiquitous very soon. This also has far-reaching consequences and opportunities for SCM.

DHL (2019) confirms that AI is rapidly transforming the way LSPs operate as a result of the ongoing trend towards automation and continued improvements in computing (See Table 2). AI will augment human expertise through systems that help generate novel insights from big data and eliminate difficult tasks for humans. In logistics AI will in the next years enable back-office automation, predictive operations, intelligent logistics assets, and new customer experience models. Performance, accessibility, and costs of AI continue to improve thanks to major advances in big data, algorithmic development, connectivity, cloud computing, and processing power. With AI, logistics networks can be orchestrated to an unparalleled degree of efficiency, redefining industry behaviors and practices. As such, AI will be instrumental to help 4Cs to process the enormous datasets that will become available once they go live on a large scale. All decisions that currently are made by humans (usually assisted by customized planning software) are now to be made in a single control center, see Section 2.3. It is expected that this will only be possible with the help of AI.

Back-office AI presents a significant opportunity to streamline the internal functions of logistics corporations such as accounting, finance, human resources, and IT. Here, cognitive automation can be applied to critical logistics tasks such as ensuring the most updated customer addresses to bolster successful deliveries.	**Predictive logistics** can be enhanced by AI to shift the logistics industry from operating reactively with planning forecasts to proactive operations with predictive intelligence. An example is predictive demand planning using data from online shops and forums to predict unexpected volume spikes for trending products. LSPs and suppliers can then avoid costly overstocks or out-of-stock situations that result in lost sales for both the supplier and the consumer.
Seeing, speaking & thinking logistics assets empowered by AI can greatly relieve the physical demands of modern logistics work. Applications include the use of AI-powered robotics solutions and AI-based computer vision systems which can augment much of today's logistics operations such as material sorting, handling, and inspections.	**AI-powered customer experiences** can further personalize customer touch points, drive shipment volumes, and increase customer loyalty and retention. For example, the use of conversational AI interfaces (e.g., Amazon Alexa) can enable LSPs to streamline interactions and be more attuned to their customers' needs and developments.

Table 2. Four main areas of AI applications in supply chains.

TNO (2020) recently issued a position paper on the role of AI in logistics systems. They subdivide AI application in the categories 'Sensing', 'Thinking' and 'Acting'. Then they discuss AI innovations such as traffic behavior, intelligent emission management, maintenance planning and smart loading. The authors conclude that AI can contribute to the development of an integrated mobility and transport system that will strengthen the Dutch economy using new technologies.

Schniederjans et al. (2020) have also produced an overview of supply chain digitization trends, with special attention to AI. They analyzed that the external communication between human beings averages approximately 10 bits per second, whereas robots can communicate at rates over one gigabyte per second.

Facets like *machine learning* (ML) and artificial intelligence are further enhancing the use of robotics. ML is a subset of artificial intelligence where computers are given the ability to progressively improve their performance on a task with data but without the need for explicit programming. However, individuals are still needed to optimize the use of these technologies for supply chain network performance. This confirms the need for effective organizational and business models around these technologies.

Although digitization developments including AI seek to automate learning and optimization in organizations, the proliferation of these technologies have not yet reached the more strategic areas of SCM, such as network design and cross supply chain orchestration. This makes it even more even important to think about how 4Cs should be organized, staffed, and made scalable by leveraging AI and ML techniques. Once that is ensured, AI technologies will enable 4Cs to create efficiency levels that are completely unattainable for supply chains that are managed individually.

2.3 OPTIMIZATION CAPABILITY

The fruits of the increased possibilities offered by the digitization progress in supply chains can only be reaped if the huge data that becomes available can be effectively translated into improved decision making. In other words, do we have the optimization potential in a 4C to work with the immense data coming from multiple individual supply chains with their own definitions, execution, contracts, legal obligations, etc.? This question is of course broad and has many aspects that can be discussed. To focus ourselves to the application of optimization capabilities in supply chain orchestration, we briefly discuss the following four subtopics: 1) Computing power, 2) Real-time optimization, 3) Digital twins and simulation, and 4) Optimization software developments.

2.3.1 Computing power

The 4C concept assumes that multiple supply chains are coordinated and optimized as if they were a single supply chain, while still satisfying company-specific restrictions. Logically, this brings a great challenge to solve bigger and bigger optimization problems. Since most supply chain planning and optimization problems are NP-hard, the computation time to reach the global optimum increases exponentially with the problem size. Next to the possibility to use heuristics to strongly reduce calculation time through sacrificing some of the solution quality, fortunately there is also the development of powerful (cloud) computers that can solve bigger and bigger optimization problems within a given allowed calculation time. As Karaenke et al. (2019) put it, recent advances in optimization potential and computing power allow for more coordination and provide new and promising approaches to solve daunting orchestration problems in (retail) logistics and possibly other applications in SCM that have not been available only a few years ago.

Basic optimization problems in operation research such as the Travelling Salesman Problem that were impossible to solve top optimality ten years ago are now solved in a matter of seconds or minutes. The driving force behind this is Moore’s law (See Figure 6) which states that computing power measured in the number of transistors on integrated circuit chips of the same size grows exponentially, roughly doubling every two years.

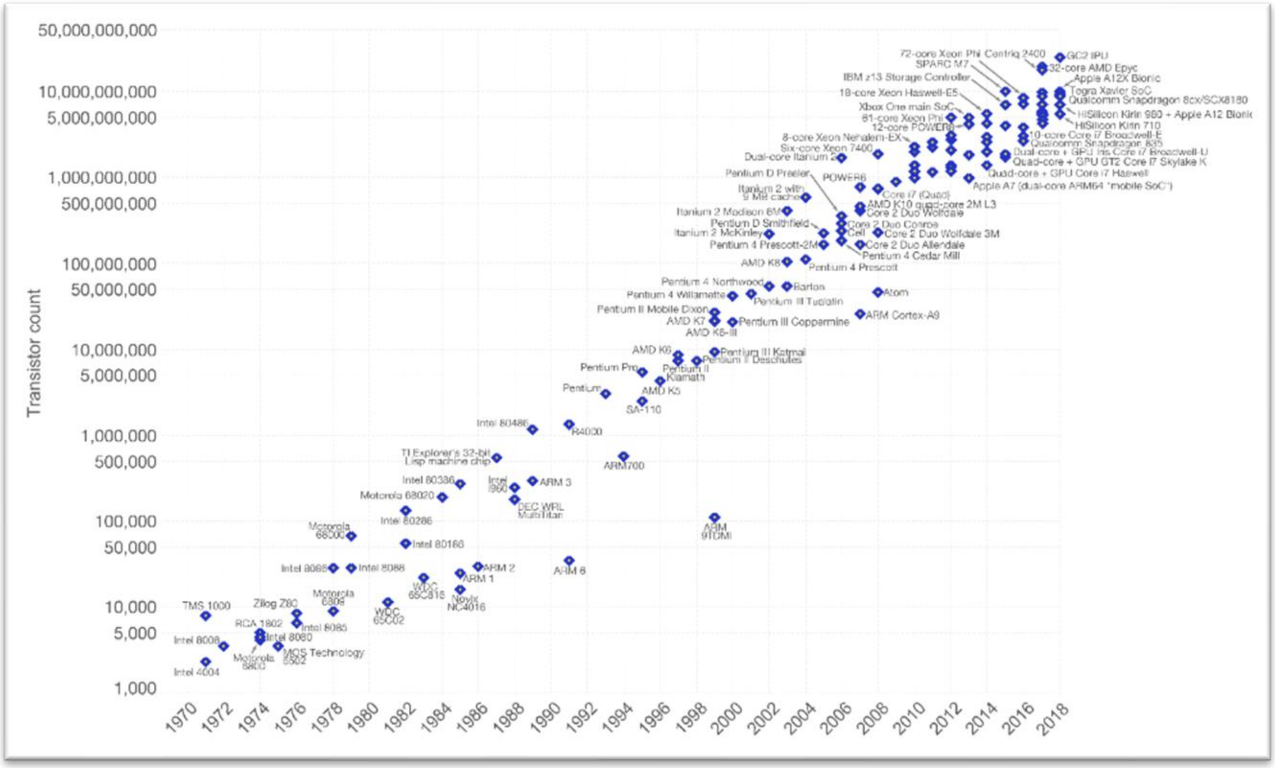

Figure 6. Moore's law[10]

2.3.2 Real-time optimization

Until recently a lack of real-time information of logistics resources was common in the logistics industry (Liu et al., 2019). Historically, this resulted in increased logistics cost, energy consumption, logistics resources consumption and low load factors. In the absence of real-time information, it is difficult to achieve efficient, high-quality and sustainable logistics services, especially given the increasing logistics service requirements. To deal with such challenges, real-time dynamic optimization strategies for logistics optimization and coordination are proposed in literature and developed by commercial software houses. Using IoT enabled real-time status of vehicles and carriers a 4C can make optimal planning decisions combined with the actual status on the road, rail, or water. In addition, such real-time information can be shared with other stakeholders in the supply chain. There is ample evidence from literature (e.g. Liu et al, 2019) that including real-time information contributes to reduced logistics cost and fuel consumption, and improved vehicle utilization rates.

2.3.3 Digital twins and simulation

Giusti et al. (2019) define a digital twin as an information entity that mimic the features of a physical entity. These features concern the properties, state, evolution, and operations carried out by the physical

[10] Source: Wikipedia (https://en.wikipedia.org/wiki/Transistor_count)

entity. A recent review of digital twins and their applications is conducted by Tao et al. (2018). Historically used in industrial settings, digital twins can be applied to supply chains as well. This is especially important for 4Cs where combinations of supply chains are dynamic and cannot depend on historical knowledge like is common in traditional supply chain planning. For example, shipments can be represented by digital twins that provide up-to-date information on their state. Moreover, digital twins can be used for simulation purposes to test critical decisions, such as modal shift or bundling of shipments.

Simulation is a technology that uses offline systems to show the potential benefits of alternative solutions. It can be used in a model or digital twin of the real world and to then add or modify some characteristics in a safe testing environment. In this way it is possible to better understand the benefits of applying new concepts such as supply chain collaboration or to take more conscious operational decisions in the real world.

Digital twins are not quite common in logistics analysis yet. But there are some interesting initiatives in this field that are worth mentioning. The LEAD project sponsored by the EU (starting in 2020) will apply the digital twin concept in the area of urban logistics, which is a very suitable area given the many stakeholders and decision makers that all interact in a complex and small geographical area. A digital twin will be used to model the current and future behavior of an urban network in a variety of conditions and configurations, anticipate failures and optimal schedules for operation and simulate possible policy effects. The digital twin evolves with the city by bringing together relevant data from a variety of sources and by receiving real-time city data through sensors (i.e. big data from urban platforms and real-time traffic data). Given the complexity of combining the planning of multiple supply chains together, also 4Cs provide a very suitable environment for making use of digital twins, especially for companies considering joining a 4C or not. Without the risk of making a drastic change to their current supply chain setup, a digital twin can help to test the risks and benefits of joining a 4C.

2.3.4 Optimization software

A final optimization capability development that is useful to mention in the context of horizontal collaboration and 4C is the increased availability of dedicated software tools aimed at large scale supply chain optimization. Gansterer and Hartl (2018) mention that especially centralized entities (such as a 4C) typically face huge and complex optimization problems, since they must plan operations for several individual, but interconnected fleets. Thus, sophisticated solution techniques are required. There is a vast field of problems and methods that have not been investigated so far from a collaborative perspective. In their directions for further research Gansterer and Hartl (2018) propose to investigate how a 4C exchanges requests among collaborators, while trying not to redistribute more than necessary. This would lead to a 2-objective problem, which minimizes 1) total cost and 2) the deviation from the decentralized solution. A related question is how the 4C can motivate participants to reveal their data. These incentives might be provided by using smart profit sharing mechanisms or, e.g., side payments. Finally, since central decision makers face huge optimization problems, the application of solution methods for large scale VRPs are supposed to further improve the success of supply chain orchestration. For this purpose, advanced processing methods like parallel computing should be considered.

Fortunately, also many powerful algorithms and tools from the commercial area and academia have become available in recent years. Figure 7 shows the typical subdivision of supply chain analytics tooling into four areas: descriptive analytics, diagnostics analytics, predictive analytics, and prescriptive analytics.

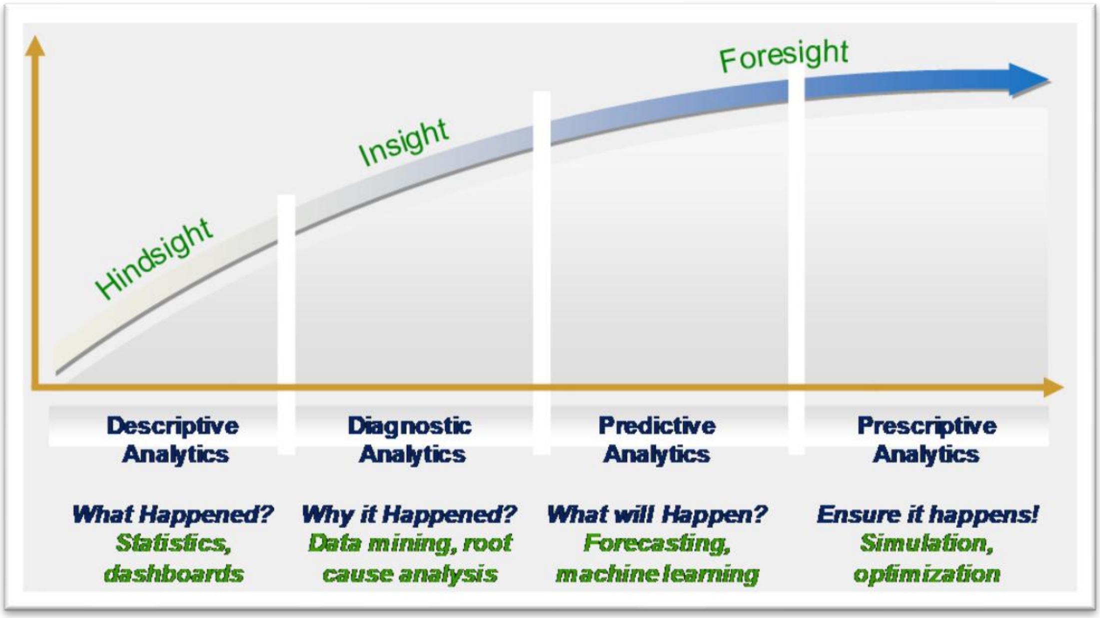

Figure 7. The four areas of (supply chain) analytics

In each of these categories more and more (usually licensed) software tools become available. An overview from 2018 by Gartner can be found in Figure 8. And looking at data science a bit broader than the pure supply chain optimization tooling, Figure 9 shows a number of software categories that are supportive to supply chain optimization, i.e. programming languages, data platforms, deep learning, machine learning, data exploration, data ingestion and general development tools. All these tools are valuable pieces of the data analytics jigsaw puzzle that comes with the 4C concept.

Figure 8. Gartner Supply Chain Optimization Magic Quadrant

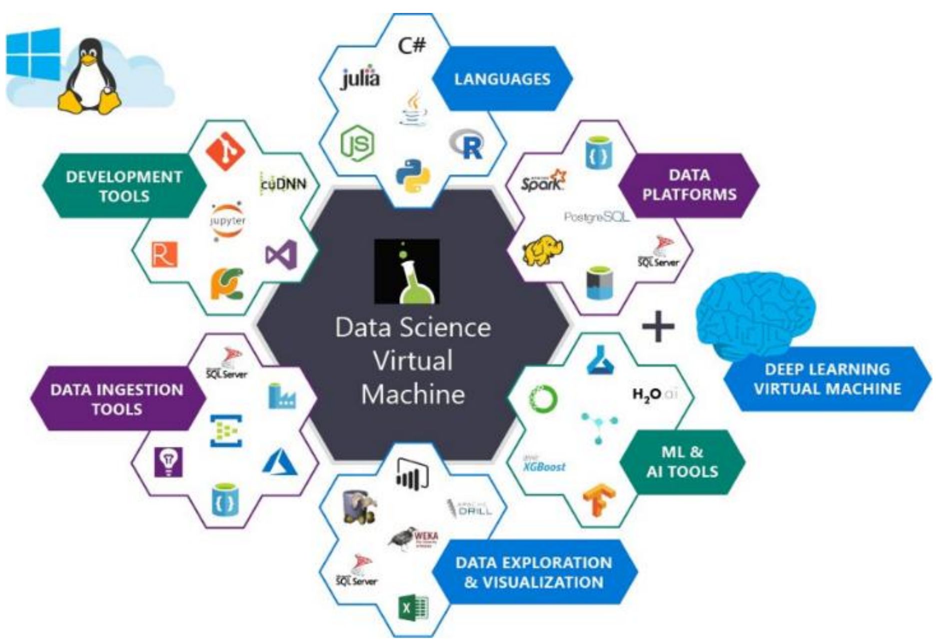

Figure 9. The Data Science toolkit[11]

[11] Source: radacad.com/data-science-virtual-machine

From a more academic perspective, Arunachalam et al. (2018) provide a comprehensive literature review on ‘big data analytics’ in supply chains. Figure 10 shows how big data analytics developed out of pure statistical techniques on the wave of strongly increased availability of data. Figure 11 illustrates the importance of the topic of big data analytics in recent academic supply chain literature.

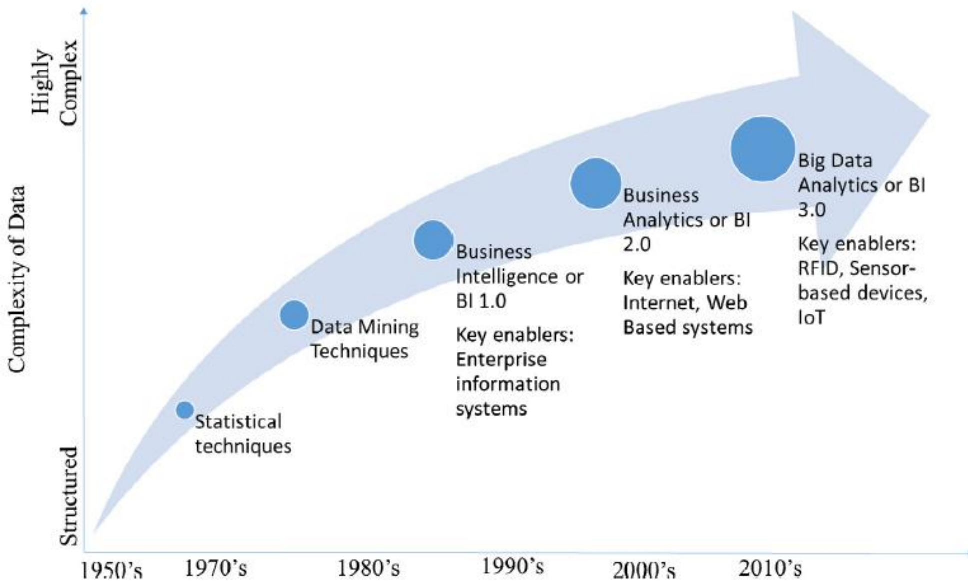

Figure 10. Complexity of data over the last 70 years (Arunachalam et al., 2018)

Search terms	SCOPUS	WoS
“Big Data” and “Supply chain”	104	65
“Big Data” and “logistics”	101	30
“Big Data” and “operations management”	15	8
“Big Data” and “operational performance”	1	1
“Big Data” and “operations research”	6	3
“Business Analytics” and “supply chain”	10	13
“Business Analytics” and “logistics”	6	4
“Business Analytics” and “operational performance”	2	2
“Business Analytics” and “operations management”	3	3
“Business Analytics” and “operations research”	4	5
“Business Intelligence” and “supply chain”	64	35
“Business Intelligence” and “logistics”	39	17
“Business Intelligence” and “operational performance”	7	4
“Business Intelligence” and “operations management”	3	3
“Business Intelligence” and “operations research”	6	3
“Business Intelligence” and “operational performance”	7	4
“Supply chain analytics”	8	4
“Supply chain” and “predictive analytics”	16	13

Figure 11. Peer-reviewed papers on supply chain analytics and related topics between 2008 and 2016

Based on this vast body of literature, the authors categorize the data analytics capability of companies or supply chains by enriching the descriptive, diagnostic, predictive and prescriptive categories with a dimension of how strongly these analytics capabilities are embedded in the organization. Using these two axes, companies can be positioned in the adoption stage, initiation stage or the routinization stage, as can be seen from Figure 12.

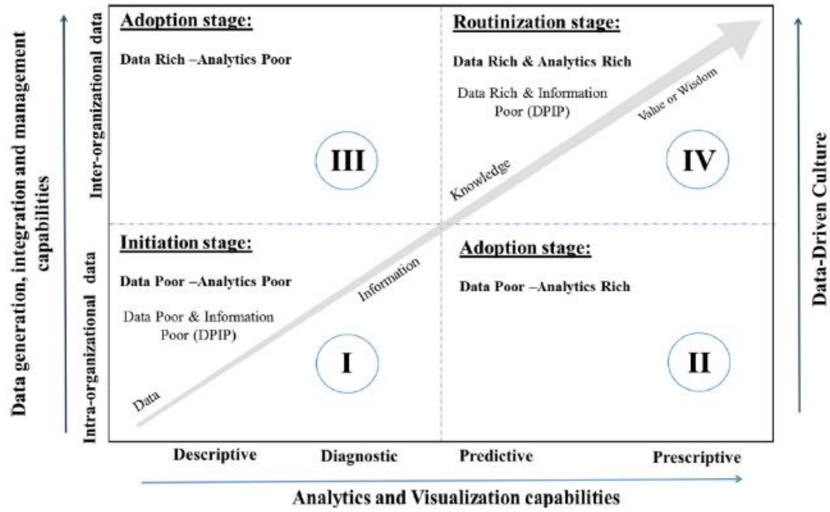

Figure 12. Big Data Analytics capability framework for supply chains

2.4 Globalization, (political) instability and the Corona pandemic

A final general topic that impacts the applicability of supply chain collaboration and 4C are the international developments such as globalization, political instability and the Corona pandemic.

Historically, the EU is the world's largest exporter and biggest trader in goods. Moreover, it is estimated that in the next 10-15 years, 90% of the world's growth will come from outside the EU (ALICE, 2015), so the EU has every interest in making sure that its companies remain competitive and are able to access new markets and benefit from these sources of growth. Globalization entails joining global value chains and delivering products, services, and technologies that no individual country would be able to produce on its own. In this context, logistics is a key enabler for global trade.

Regarding globalizing trade, Veenstra and Zuidwijk[12] note that the Dutch (and European) distribution logistics show a problem. The current logistics system is designed for very precisely planned delivery of stores, a tight utilization of truck capacity and a strict regulation by (local) authorities. Such a setting does not lend itself very easily to scale up in a response to demand peaks. Especially in the last mile, trucks are already planned and to their full capacity, and the number of trucks is optimized to reach the most cost-effective distribution execution. But the Corona crisis brings forward the question whether this is really the best setup for logistics processes. It would probably be better to also prepare for abnormal circumstances and major disruptions. The Corona crisis might be a 'Black Swan event', but in recent years society and the logistics industry have been confronted with things like Brexit, international terrorism, natural disasters, climate change, etc. These phenomena and the countermeasures that are taken by governments and companies hugely impact supply chains. For individual companies it is almost impossible to prepare for such scenarios. Extensive collaboration through a 4C can bring a solution. In the Netherlands for example, in the early phase of the Corona Crisis the logistics industry has already started redistributing logistics capacities between industries that see deep troughs in their volumes (for example

[12] Dinalog Blog. https://www.dinalog.nl/blog-albert-veenstra-en-rob-zuidwijk-logistiek-en-coronavirus/

restaurant deliveries) to industries that see high peaks (for example supermarket deliveries). This example shows how vital collaboration is in the dynamic world we live in.

This report is being written in the three months directly after the first confirmed Corona patient in Europe, late January 2020. With developments are still well underway, currently all layers of governments, from municipal to EU level, are imposing fierce regulations on citizens and companies as to how to behave to fight the pandemic. Obviously, this is necessary for public health, but it comes at a high cost for the economy and will have a big effect in the years to come. It is encouraging to see how firmly governments can act when faced with an eminent crisis, in this case the Corona virus. They take the leading role in combatting the crisis as it surpasses every other layer of decision making. Suddenly, active government intervention is not objected against as has been done in the mostly liberally oriented European governments, but instead there is an outcry for fierce government intervention. This rehabilitation of a strong and active government to fight company-, sector- and even nation-surpassing challenges is a phenomenon that might be encouraging for other global challenges such as global warming and, in the context of this report, the impact of transport efficiency on sustainability. Once the worst part of the Corona pandemic will have died out, there will most likely be a new economic landscape and governments can guide their rebuilding programs by their firm sustainability ambitions. The pandemic was able to spread quickly partly because of massive long-distance travelling and long global supply chains. This might be reviewed once the pandemic is over. Adding to this, citizens will notice the ‘collateral benefits’ of the Corona crisis such as cleaner air in metropoles, reduced CO_2 emissions, and higher working day efficiency in certain industries due to conference calling instead of daily commutes and business travel. In the end, the pandemic might show that there is a limit to economic growth under our contemporary circumstances, and we should focus more on making our current economic activities more efficient, rather than on increasing the size of our economies.

3 LOGISTICS DEVELOPMENTS IMPACTING HORIZONTAL COLLABORATION

In the previous chapter we have introduced four major trends that are observed in virtually all countries and industries. In this section we zoom in on recent developments specifically within the logistics industry that impact the formation and success of horizontal collaborative initiatives. The holistic supply chain point of view we take in this report implies that we also investigate how logistics processes are (or perhaps should) be impacted by urbanization, security concerns, automation, the sharing economy etc. And we will study how these developments impact logistics collaboration.

A valuable resource when discussing recent developments in logistics, is the latest DHL trend radar report (2019). Figure 13 summarizes the main trends observed, categorized by the time they are expected to become relevant to the wide logistics industry and their expected impact.

Figure 13. DHL Logistics Trend radar (2019)

In the next subsections, we discuss some of these trends of which we believe that they are of special importance to the development of 4Cs, as well as a few developments that are not represented in the figure. In any case, it is clear from the picture that logistics is a dynamic field where a lot will change even in the next five years already. The topics that we will discuss next are: 1) Standardization, 2) Labor market developments, 3) Urbanization and City Logistics, 4) Security, 5) E-commerce, 6) Autonomous vehicles, 7) Physical Internet, 8) Logistics Marketplaces, and 9) The Sharing Economy.

3.1 STANDARDIZATION

One impediment to horizontal collaboration at large or for 4Cs in particular is that it is very difficult to combine goods from various industries into the same vehicle, vessel or train, because of specific characteristics of the products and the load carriers used (see section 7.1). Whereas this issue is mostly solved for collaboration within specific industry sectors (ref. ISO pallets, (refrigerated)containers, etc.), absence of logistics standardization is still a large hurdle for collaboration across industries.

DHL (2019) mentions smart containerization as an important upcoming innovation. They argue that the adoption of the standard container revolutionized global cargo shipping, bringing vast improvements in efficiency and ease of trade. However, the growing need for flexibility and increasing time and cost pressures will require new container formats and processes, especially in the context of shared logistics networks and urban delivery. New packaging formats are also essential to handle the rise of single shipment volumes from e-commerce.

The EU funded project Modulushka focused on the development of standardized containers and boxes to enable freight bundling and horizontal collaboration. The goal of the project was to develop iso-modular logistics units of sizes adequate for intermodal and co-modal flows of fast-moving consumer goods (FMCG), providing a basis for an interconnected and orchestrated logistics system for 2030.

Another aspect that hinders the regular exchange of shipments either via a control tower is brand-related: companies with a strong brand image often have difficulties with giving up their brand visibility on trucks. This could hopefully be resolved by multiple or projected logo's on shared trucks, accompanied by logos of neutral certification entities like US Smartway, or EcoStars or the Dutch Lean & Green.

3.2 LABOR MARKET

A recent report by European Road Freight Transport (2018) concluded that European road transport firms will soon be facing a driver shortage of 150,000 unfilled jobs. In only six countries (the UK, Germany, France, Denmark, Sweden, and Norway) the shortage of drivers adds up to 127,500. The UK has the highest shortage (52,000 drivers) but is closely followed by Germany at 45,000 vacancies. In Germany, the DSLV transport union reports that in the next 15 years, two-thirds of drivers will retire.

This alarming situation can, ceteris paribus, only be solved by automation (see section 3.6 on autonomous vehicles) or by dramatic efficiency increases in transport. When widely adopted, horizontal collaboration is an innovation that can establish this efficiency increase.

3.3 URBANIZATION AND CITY LOGISTICS

Globally, urban areas are growing and the fraction of the global population in rural areas is shrinking. Large cities are becoming very densely populated, and the associated congestion is escalating. Since 2007 more than half of the world's population lives in urbanized regions, in several western countries this percentage is already well above 70%.

At the same time, e-commerce is growing quickly especially in these cities and consumers expect shorter and shorter delivery times. This places considerable importance on the design of smart, sustainable, and secure supply chains into the cities, and it increases the need for advanced and innovative technologies to plan and execute logistics, with a high level of collaboration and automation. We will come back to this when discussing the Physical Internet in Section 3.7. As Ferrell et al. (2019) state: the current paradigm of accepting inefficiencies to avoid collaboration with competitors for freight movement is a luxury that will no longer be workable. Concepts of 4C and horizontal collaboration can be expected to evolve from a nicety to a necessity in urban areas first.

In their recent report the World Economic Forum (WEF, 2020) states that there has never been a time of greater change for the 'last mile' than today. Consumers order more things online, expecting more control and faster deliveries. Disruptive technologies such as droids and drones are shaking up entire delivery chains. Emerging tech players such as Uber Freight and Postmates are changing the dynamics of the competitive landscape. However, these developments have a downside: Inner cities are struggling with traffic congestion and air pollution due to the increasing number of delivery vehicles, their emissions and second-lane parking. Some cities predict that if no interventions are made, inner-city traffic will be seriously disturbed in the next three years.

Femke Halsema, Mayor of Amsterdam

"The city of Amsterdam is expected to have 1 million citizens in 2032, a growth of 20% compared to today. The number of jobs is expected to grow by 30% until 2040. The additional volume of traffic will lead to severe bottlenecks on the road and in public transport. Especially urban deliveries – mostly linked to the soaring e-commerce growth rates recently – cause structural problems to the city of Amsterdam. Currently, one in eight vehicles in the inner city is a truck or a van. Many old bridges and quays are not designed for the heavy loads and intensive use these days. Also, delivery vans cause gridlock, as these vehicles park on the street or in busy inner-city areas. Also, they present a safety risk to our many bike users and pedestrians. To combat this development and achieve our decarbonization targets, we have put a plan in place according to which the inner city will be free of fossil-fueled trucks and vans by 2025, causing a 77% reduction in NO2, and a 42% reduction in CO_2 from all of the traffic in the city, including passenger cars."

Figure 14 from WEF (2020) provides an overview of the most prominent city logistics measures that can be taken. Especially the interventions of multi-brand parcel shops, load pooling and Urban Consolidation Centers (UCC) require intense collaboration, even with competitors.

Figure 14. Overview of 24 prioritized last-mile interventions (WEF, 2020)

Muñoz-Villamizar et al. (2017) assess the implementation of an electric fleet of vehicles in collaborative urban distribution of goods, in order to reduce environmental impacts while maintaining the usual service level. They test their approach in a real-life setting in the city of Bogotá, Colombia.

Finally, Cleophas et al. (2019) discuss the important role of horizontal collaboration and supply coordination in urban logistics. In their work, they collect and discuss contributions to collaborative freight transport in urban areas from recent publications (i.e. those published during the past ten years). They particularly analyze vertical and horizontal approaches of collaboration from an operations research perspective and point out strategic, tactical, and operational planning problems and solution approaches. To highlight research gaps and future research opportunities, they present innovative examples of collaborative urban transport and analyze factors of failure and success.

3.4 SECURITY

With the digitization of transport logistics comes increased (digital) vulnerability. For example, many incidents in Europe emphasize how freight systems can be manipulated, data hijacked by ransomware, or information stolen. Cyberattacks threaten the availability and validity of data and can seriously harm a supply chain. Current transport management systems and some onboard technology were not designed with security as a primary factor. The ability to use sensors that indicate the occurrence of security events during transport would be invaluable for risk awareness. After all, cargo on the move is much more vulnerable to theft than goods stored in a warehouse. Indeed, most cargo theft (85%) involves trucks, and those thefts cost businesses more than $10 billion annually worldwide (Ferrell et al., 2019).

The digital threat to transport logistics cannot be solved by one company or one solution. The transport system is a complex network and nowhere is this more true than in a collaborative logistics setting, where every link in the network contributes to the risk or the security of the system. After all, a collaborative network logically includes more actors and more information sharing than traditional singular supply chains. Clearly, efforts aimed at increasing the prevalence of collaborative arrangements are likely to increase this risk, see for example our discussion on the legal framework for collaboration in Section 5.7. It is fair to say that networked models such as 4Cs are as strong as their weakest link. The demand for constant online communication creates opportunities for hackers to exploit weak security practices on the account of a single actor in a network. Moreover, while a cyberattack aimed at stealing employee or customer data remains the most talked-about risk, attacks designed to deny or disrupt service are also gaining popularity. These attacks can seriously jeopardize production and delivery schedules and cause delays that can have rippling impacts on customers and their customers' customers (Ferrell et al., 2019). Security therefore is a topic that must be paid special attention to when designing a 4C.

3.5 E-COMMERCE

A further important logistics development that has already been touched upon in the previous sections is the rapid rise of e-commerce, and the resulting pressure on logistics systems. Supply chains need to take the development of e-commerce opportunities into account, but at the same time (and perhaps even more strongly) e-commerce itself will also influence the logistics networks that perform the physical activities related to e-commerce. This challenge is felt more and more, not only in logistics operations, but also on the side of government regulation. The large e-tailers become bigger and bigger and their influence on both supply chains and cities is also growing rapidly. In a recent interview by Link2Logistics

Alex van Breedam in a recent interview warns for this development, which he calls *Amazonization.* The few gigantic e-tailers will take their logistics execution more and more in their own hands and before long they might have the scale to implement their own physical internet, but based on their own terms and their own commercial logic. (See Section 3.7 on the physical internet).

Amazon has a clear strategy to vertical integrate logistics activities into their own company. For example, they have an airplane fleet that is planned to reach 70 own airplanes already in 2021, while they airline was only started in 2016. In one year, Amazon ordered 20.000 big Mercedes delivery vans, 2.000 special vans at Spartan and no less than 100.000 electric vans at Rivian. Within a few years it is expected that Amazon will own more delivery vans than UPS or FedEx. In addition, Amazon also started its own ocean shipping line, long haul transport company and a freight brokerage firm (See Figure 15). Overall, Rakuten Intelligence estimates that Amazon now ships about 50% of their parcels without using any external LSP. In 2017, this percentage was only 15%. Amazon denies these figures, but its strategy to take over control of the entire journey of their parcels to the final customers is clear.

Figure 15. Amazon as logistics executor

Amazonization in a way is an alternative for collaborative logistics and 4Cs: bundling of flows and efficiency of transport is reached by the sheer size of a dominant company. Although this might be beneficial for some macro logistics KPIs, this comes with several threats. First, one single commercial entity will control transport, see buying behavior and own loads of consumer data. This renders this company enormously powerful and difficult to regulate for governments. The fragmented transport industry may gradually develop into an oligopoly or in the end a monopoly which is not in the best interest of consumers. It also makes it impossible for SME transport entrepreneurs to compete against the dominant player. Under a

4C concept these disadvantages are not there, but as experience shows collaboration in tough to organize quickly. And if it takes too long, the likes of Amazon may have gained a deciding advantage.

3.6 Autonomous vehicles and Platooning

The development of autonomous vehicles is progressing rapidly, also with an increasing focus on commercial transport vehicles. Amazon is a leading player here as well. While these autonomous vehicles could be used to replace trucks in existing systems and networks, and managed and controlled in traditional ways, Ferrell et al. (2019) argue that they also present novel opportunities to strengthen logistics collaboration. The availability of vehicle-to-vehicle communications offers information to transport planners that will enable them to better predict traffic conditions and arrival times, and provide opportunities for resource synchronization, thus making control tower concepts with fewer human planners per operated truck more viable.

Autonomous vehicles will likely be operated for longer periods of time, will be routed and re-routed more effectively and dynamically, and will be cheaper to operate. For example, there is no need anymore to return to the home base of the driver on a regular basis. In principle, the truck could embark on an endless pickup and delivery journey until it needs maintenance. This brings an interesting research opportunity for researchers as it changes the classical vehicle routing problem where typically a truck must return to its depot at some point in time.

All these characteristics have the potential to enable collaboration through 4Cs, and indeed they may help to address some of the potential roadblocks and challenges inhibiting horizontal collaboration in some settings. TNO (2020) however warns that autonomous vehicles still have quite some hurdles to take before they will be allowed on the road. One obvious consideration is the interaction with vulnerable road users such as pedestrians and cyclists. But also, it is still unclear how the vehicles will and should cope with incomplete information such as reduced sight because of other (moving) objects around them.

Figure 16. Volvo's electric autonomous vehicle Vera[13]

A promising semi-autonomous arrangement is the concept of platooning, small convoys of trucks that drive automatically. One or two trucks follow the actions of the first driver at 0.3 seconds from the vehicle ahead: accelerating, steering, braking. These actions are automated using vehicle mounted sensors, such as radar, sonar and cameras. The advantages of platooning are fuel savings, lower CO_2 emissions, improved road safety and better traffic flow. Janssen et al. (2015) expect that in a few years' time, market introduction will be possible.

3.7 Physical Internet

One of the recently proposed logistics innovations is the concept of the Physical Internet. This was first introduced in a book by Ballot and Montreuil (2012). The Physical Internet (PI) works based on horizontal collaboration and consolidation. It is called the Physical Internet because of its similarities with the Digital Internet. In the Digital Internet, providers are only responsible for links between servers, instead of the whole routes. PI applies this idea to physical flows. A supplier is connected to the PI, sends its freight to the network and the PI will get it to its destination. This is quite different from the current situation, where usually each firm has its own (customized) supply chain network, whether it is inhouse or subcontracted to an LSP.

The PI network consists of open warehouses and/or open cross-docking hubs (so-called PI-hubs). In principle, these are available for every LSP and every type of shipment. Open warehouses have the capacity to store goods, while at cross-docking hubs this space is limited. The latter will mainly be used as transit points where goods will be only be stored temporarily (usually a couple of hours). An important aspect of the PI is standardization. As it should be able to transport and cross-dock all kinds of goods,

[13] Together with Vera Volvo also develops a system design for collaborative networks of autonomous vehicles that shows some similarities with the 4C concept.

these should be packed in a standardized manner so that they can be transported together. Some effort has already been done to come up with designs of these modular packages, so called π-containers. Open warehouses and PI hubs do not widely exist yet, but several papers study possible designs for these terminals, e.g. Ballot et al. (2012), Meller et al. (2012), Montreuil et al. (2013).

Several simulation studies have been carried out to investigate the potential benefits of the Physical Internet. Hakimi et al. (2012), show a significant decrease in the total distance driven. Another study, by Sarraj et al. (2014), finds a reduction in total costs (5-30%), lower CO_2-emissions (13-58%), and a higher weight fill rate (from 59% up to 65-76%), depending on the different scenarios and designs of the network. Furtado et al. (2013) also show social benefits, as truck drivers for example spend more nights at home under a PI transport model. As more intermediate cross docks will be used in the PI, drivers will commonly shuttle between two hubs instead of driving the whole route.

Since the presentation of the PI concept by Montreuil et al. (2012), the European Union has embraced it as the central vision for future supply chains towards 2050. Concerning 4C, ALICE (2015) states that the PI represents the technological and informational basis for future coordination and collaboration in supply chains. ALICE proposed a road map to arrive at the PI towards 2030 (being adopted at large scale in 2040). This road map is shown in Figure 17.

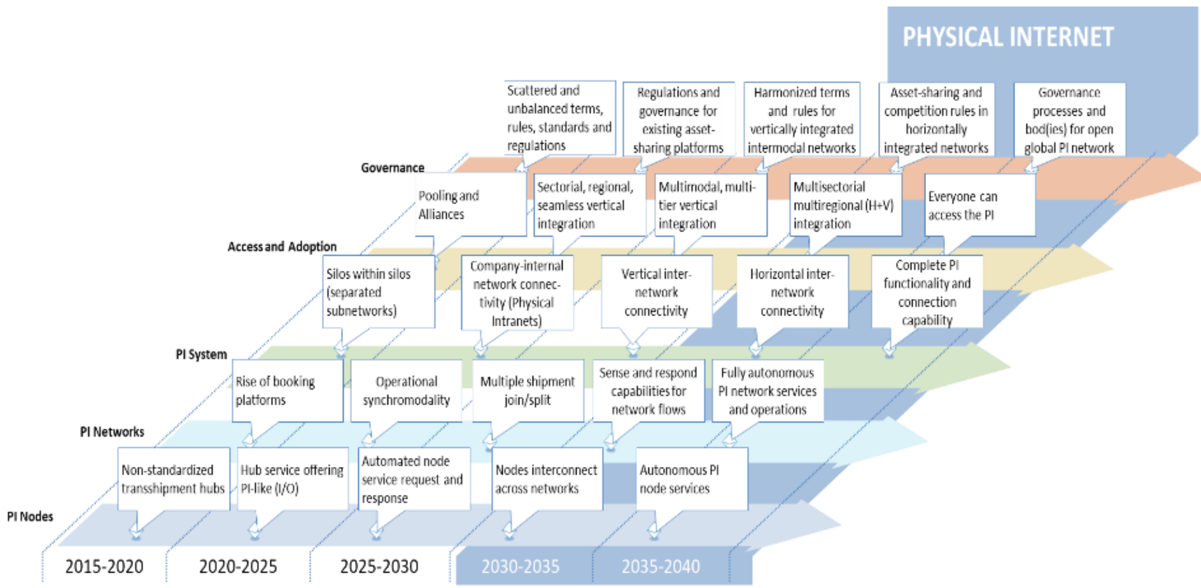

Figure 17 ALICE PI roadmap 2015-2050

As the roadmap shows, the PI will not materialize overnight. Various steps need to be taken to move into the direction of the PI in one form or another in the future, one of which is intensified collaboration. Although the PI is one network, it is not envisaged that there will be only one operator. Multiple operators will exist next to each other, each responsible for a piece of the network. Here the analogy to the digital internet also comes into play, as these operators will have a similar role to that of internet service providers.

According to ALICE (2015) the two most important strategic drivers towards the PI are:

- Increasing the service level to the consumer of products and services in the most efficient and sustainable way.
- Lowering the barriers to enter new geographical markets and for consumers to have access to new products.

Full realization of the PI concept means that logistics assets and services cease to be a differentiator, as they will be fully standardized, integrated and shared on a global level. In other words, supply networks will become a commodity that is available to any sender and receiver. In a fully developed PI, competition will be no longer based on owned and individually optimized supply chains. Instead, higher-level logistic functions, such as network planning, after-sales services, and advanced stock allocation, will drive the competition among supply chain leaders.

PI is still a concept, not a reality. But if PI will become the new standard in future logistics (and not the vertically integrating e-tailers discussed in Section 3.5) it most likely will be realized in a gradual process where global supply networks evolve through three subsequent stages:

1. Fully owned supply chains, where the assets and services are key constituents of the company products/services, as differentiators for the customer. This is the current situation.
2. Horizontal collaboration and vertical coordination in a limited network of companies, sharing what are considered ‘commodity’ assets and services.
3. Physical Internet for most goods, in a collaborative network involving many parties who are implicitly collaborating, with the lowest costs and maximum availability and service level.

From step 2 onwards, the PI has many commonalities with the 4C concept. Whereas the PI originates from a mostly technical idea, 4C focusses more on the organizational or business model questions around collaborative and integrated logistics processes. In a way, the PI is the automation of a 4C, and 4C a business model within the PI.

3.8 LOGISTICS MARKETPLACES

Another development in logistics that is gaining traction and facilitates transport flow bundling is the growth of so-called logistics marketplaces, or freight marketplaces. Freight marketplaces match companies looking to ship freight using one or multiple modes of transport (road, air, ocean, and/or rail) with suppliers or brokers of logistics capacity. Customers benefit from better comparability and transparency of proposals, optimized price/performance ratios, and high security through member certification and rating systems. LSPs can use these platforms to digitalize internal processes as well as maximize capacity utilization.

The integration of logistics marketplaces with 4C control towers through central planning, reporting, dispatching, and tracking tools will further enhance its impact. Karaenke et al. (2019) explore mechanisms for freight auctions and discuss computational and strategic problems that need to be solved to coordinate carriers optimally in freight marketplaces. They show that such mechanisms can for example decrease waiting times significantly. The goal of these auctions is to maximize efficiency. They study congestion at loading docks of retail warehouses as a substantial problem in retail transport logistics and as example of a coordination problem. The difficulty is that carriers optimize locally, leading to globally suboptimal outcomes. Still, logistics marketplaces are a relevant building block of collaborative logistics. Mutually benefitting from each other's capacities brings more structural coordination through a 4C one step closer.

3.9 Sharing economy

The final logistics development in the light of the 4C concept that we discuss is the sharing economy. Sharing is especially important in dense urban areas, where space is scarce, and optimal utilization of resources is essential. The success of companies like Airbnb and Uber has been made possible by evolving technologies, enabling consumers to share information fast and in a secure way. Traditional business models must be adapted, and firms must learn how to compete in a world of shared idle capacities (Gansterer and Hartl, 2020).

The concept of shared transport resources is a hot topic in transport and logistics (Speranza, 2018). This can be explained by the growth of the e-commerce sector, which boosts competition and brings down prices. Customers have small order sizes but often expect same-day delivery services within very tight time-windows. Therefore, economically and ecologically efficient delivery is challenging. Empty truck miles in the EU are estimated to range between 15 and 20%. Collaborative (sharing) frameworks provide opportunities to reduce these inefficiencies considerably (Karaenke et al., 2019; Vanovermeire et al., 2014).

Also DHL (2019) observe that B2B and B2C sharing of resources, logistics assets and infrastructure can increase capacity utilization while reducing costs and the carbon footprint of transport. LSPs can participate and share their own underutilized assets such as delivery vehicles and forklifts as well as warehousing space with an on-demand approach.

The difference between the sharing-economy and true horizontal collaboration is that with the sharing economy typically the collaboration or exchange is a short-term or one-off exercise, whereas horizontal collaboration and 4C aim to structurally combine assets to improve efficiency. In that sense, the sharing economy is fully decentralized, whereas 4C assume centralized coordination of some kind.

4 COLLABORATION IN OTHER INDUSTRIES

In the previous chapter we have discussed a few recent logistics developments that impact collaboration in the logistics industry. Most often, these developments are aimed at improving efficiency and as a result they reduce the negative impact of transport on our climate. In the end, transport is not a goal in itself. It enables consumption, it does not generally improve it. A product is produced at location A and will be consumed at location B, all transport in between should in principle be minimized. It is therefore understandable that there is a tendency to foster collaboration to make this possible. However, as we will see in later chapters, collaboration in logistics proves to be cumbersome. Enthusiastic pilot projects are often discontinued when external funding or internal collaboration champions disappear. There are success stories of collaboration, but it goes too far to say that the logistics industry went through a major paradigm shift and has broadly switched from competition to collaboration.

We will see that in some other sectors collaboration and sharing is more common than in traditional logistics. It is argued by ALICE (2015) that many of the supply chain principles and logistics solutions applied today were developed in an era in which sustainability, globalization and the digital transformation were not paramount determinants. Therefore, it can be instructive and inspirational to look at collaboration in other industries. These other industries are selected on the basis that they still have an arguable connection with transport or mobility.

4.1 CHEMICAL INDUSTRY

Reniers (2011) discusses the drivers and challenges for horizontal collaboration in the chemical industry, based on empirical research in industrial areas around Western-European ports. Chemical companies within the Antwerp–Rotterdam area, handling ever more amounts of dangerous materials, are faced with an ever-increasing complexity of their activities. As a result, the need for collaboration between chemical firms increases. Congestion may be lowered and the efficiency and effectiveness of safety and security within the area may be increased through collaboration. Moreover, collaboration leads to more sustainable solutions and ultimately to a sustainable chemical industrial cluster. To obtain an idea of current collaboration perceptions within industrial companies, Reniers (2011) investigated collaboration drivers and partner characteristics in vertical and horizontal collaborations within the Antwerp–Rotterdam chemical cluster region.

Although cooperative arrangements within the chemical industry have a long and successful tradition, further optimization of these arrangements is still possible. By augmenting collaborative agreements and relationships and by linking up with other firms on the same level of the market, a company may enjoy options otherwise unavailable to it, such as better access to markets, pooling or swapping of technologies and production volumes, access to specialized competences, improved research and development, enjoying larger economies of scale and benefiting from economies of scope. Current industrial practice indicates that factors driving safety collaboration between companies situated within a chemical cluster include for example firefighting, emergency response, crisis management, environmental compliance and safety training. The driving forces behind the existing horizontal collaboration initiatives are either major accident risks or financial optimization opportunities. It should be noted that in case of cross-plant accident risks prevention, cost reductions can be realized through more intensified horizontal collaboration. Instead of single companies individually taking cross-plant prevention measures (and thereby possibly creating economically inefficient precaution redundancies), companies should cooperate to prevent cross-plant accidents. The same reasoning can be followed in case of security collaboration in the chemicals sector.

4.2 AVIATION

Compared to landside transport, in aviation collaboration is quite omnipresent. Key drivers are the relatively high costs per km, the increased importance of safety and the geographic clustering around airports. For example, in the area of safety, international agreements prescribe that every incident with certain minimal risk characteristics should be openly published. This makes it possible to create searchable databases such as the Aviation Safety Network[14] that has as its mission statement: "Providing everyone with a (professional) interest in aviation with up-to-date, complete and reliable information on airliner accidents and safety issues". Currently, the ASN Safety Database contains detailed descriptions of over 20.300 incidents, hijackings, and accidents.

More intense forms of collaboration can also be found in aviation, and in fact airline alliances have existed since the 1930s. Today, the three main airliner collaboration are: Skyteam (19 airlines), Star Alliance (26 airlines), and OneWorld (14 airlines), see Figure 18. There are strong economic incentives for airlines to operate dense international networks. Growth through mergers and acquisitions may provide a strong expansion of a network. However, the granting of international traffic rights is largely confined to specific carriers substantially owned by individual countries. This has left collaboration between independent carriers as an effective compromise to international carriers, thus increasing the joint market power (Fan et al., 2001). In addition to the increased customer service that is offered, aviation collaborations (in literature these are more commonly referred to as alliances) enable higher load factors for aircrafts and more efficient back office organization.

[14] https://aviation-safety.net

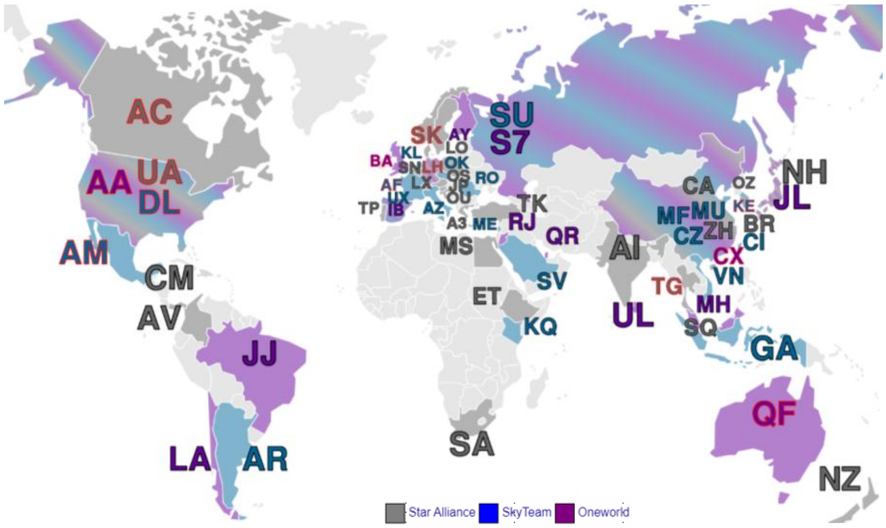

Figure 18. The three main airline alliances (Source: Wikipedia)

Benefits of collaboration for airliners are often realized through codeshare agreements. Many alliances started as codeshare networks only. Cost reductions come from the sharing of sales offices, maintenance facilities, operational facilities (e.g. catering or computer systems), operational staff (e.g. ground handling personnel, check-in and boarding desks), investments and purchases (e.g. to negotiate extra volume discounts). Traveler benefits can include lower prices due to lowered operational costs for a given route, more departure times to choose from on a given route, more destinations within easy reach, shorter travel times as a result of optimized transfers, a wider range of airport lounges shared with alliance members, and possible fast track access on all alliance members.

Airline alliances are widely studied in academic literature. A good starting point is offered by Zou and Chen (2017) who discuss the rational behind code sharing alliances. In the Netherlands, a relevant project was executed by the airport community system Cargonaut, which studied the possibilities to share airfreight data in a safe and controlled manner. It concerns data sharing between the airports of Amsterdam, Hong Kong, Singapore and Mumbai, based on a set of agreements called iSHARE[15].

For a review of other forms of horizontal collaboration specifically in the air cargo industry, we refer to Ankersmit et al. (2014).

4.3 Banking

Compared to the highly fragmented and competitive logistics industry, banking is a much more concentrated industry. There are only a small number of suppliers (banks) available and together they execute an important role in both society and the economy. Because of the limited number of companies, it is possible to initiate industry-wide initiatives much more easily than in a competitive industry with lower entry barriers such as the transport industry. Therefore, collaboration is much more visible and logical, but also tracked very closely by competition authorities. For example, in the Netherlands, it took

[15] See: https://www.ishareworks.org/en

until 2013 for banks to be allowed to bundle money transport to branches and cash machines at a single external service provider. The Dutch competition authority observed that this might reduce competition between the Dutch banks, but the (cost) benefits to consumer outweighed this, thereby allowing a beautiful example of horizontal collaboration in transport.

Another area of collaboration between banks is in online payments. For example, in the Netherlands, iDEAL is the most popular method for online payments iDEAL is owned by the Dutch organization Currence, which also owns PIN and Chipknip. As of April 2016, the total number of iDEAL payments exceeded one billion. The participating banks in iDEAL are ABN AMRO, Bunq, Friesland Bank, ING Bank, Knab, Rabobank, Triodos Bank, Van Lanschot and De Volksbank. Together they serve most of the Dutch online banking market.

4.4 The International Space Station (ISS)

The ISS is a great example to show that collaboration is possible even between unlikely partners (in this case the United States and Russia) if the stakes and benefits are big enough. The ISS program is tied together by a complex set of legal, political and financial agreements between fifteen sovereign nations involved in the project, governing ownership of the various components, rights to crewing and utilization, and responsibilities for crew rotation and resupply of the station. These agreements tie together five space agencies and their respective ISS programs and govern how they interact with each other daily to maintain station operations, from traffic control of spacecraft to and from the station, to utilization of space and crew time.

Figure 19. The 15 nations involved in the ISS

4.5 HUMANITARIAN AID

Humanitarian aid concerns material and logistic assistance to people who need help immediately, typically as part of humanitarian relief efforts including natural and man-made disasters. It is usually short-term help until the long-term help by governments and other institutions replaces it. Among the people in need are the homeless, refugees, and victims of natural disasters, wars, and famines. The primary objective of humanitarian aid is to save lives, alleviate suffering and maintain human dignity. Gossler et al. (2018) investigates situations in which Non-Governmental Organizations (NGOs) act in an uncoordinated way and reduce their bargaining power through competitive behavior. This is a commonly reported issue, which coordinating bodies such as the United Nations Clusters would like to solve. Cluster coordinators can increase the impact of disaster relief by coordinating which organizations should best cooperate to leverage maximum synergies in specific circumstances.

The UN cluster approach was adopted in 2005 to address consistent gaps and weaknesses and to improve international responses to humanitarian crises. It is a means to strengthen response capacity, coordination and accountability by enhancing partnerships and by formalizing the lead role of particular member NGOs in each of the following sectors: Sanitation, Shelter, Protection, Nutrition, Health, Food Security, Emergency Telecommunications, Education, Early Recovery, Camp Management, and Logistics.

The Global Logistics Cluster (GLC) provides coordination and information management to support operational decision-making and improve the predictability, timeliness, and efficiency of the humanitarian emergency response. Where necessary, the GLC also facilitates access to common logistics services. Based on its expertise in the field of humanitarian logistics, the World Food Program (WFP) was chosen as the lead agency for the GLC. WFP hosts the GLC support team in its headquarters in Rome. WFP also acts as a 'provider of last resort' offering common logistics services when any gaps hamper the humanitarian response.

The central role of the GLC is to act as a liaison between NGOs, where logistics operations are concerned. To that end, GLC staff organize and participate in a variety of inter-organizational fora and working groups and prepare and disseminate regular updates on GLC activities. At field level the GLC organizes and chairs coordination meetings to streamline activities, avoid duplication of efforts and ensure the optimal use of resources. An overview of the 2019 KPIs can be found in Figure 20 as an illustration of the scale of the GLC.

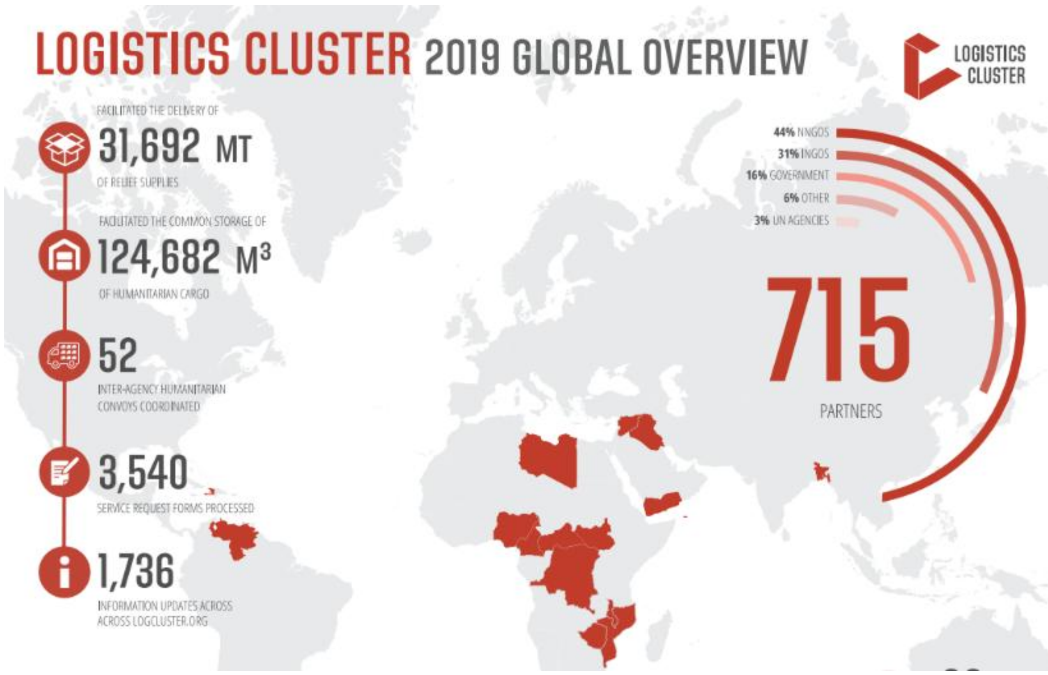

Figure 20. UN's Logistics Cluster 2019 highlights

Schulz and Blecken (2010) investigated the benefits and obstacles for horizontal collaboration between NGOs in relief operations specifically. It was concluded that collaboration leads to more effective management of relief emergencies as well as to a cost reduction. They also identified the following main impediments for coordinated action: a lack of proper perception of the importance of logistics, cultural and structural differences, mutual distrust, and inadequate capacity of relief materials.

4.6 Discussion: Innovation and absorptive capacity in logistics

In this chapter we have discussed horizontal collaboration in other industry sectors, which still had links with transport and logistics. The logical question now is how the transport and logistics industry performs compared to these other industries. In their advice to the Dutch government in which the term 4C was coined, Van Laarhoven (2008) already sent out a warning by putting forward that the transport and logistics sector has been relatively slow in innovation adoption. There are a few possible reasons for this. Firstly, the logistics industry is made up of small companies, with low profit margins and fierce competition. In addition to this, many logistics innovations require external collaboration and considerable investments in time and money.

To make a statement about the ability of the logistics sector to innovate, it is good to look at the research topic of *absorptive capacity*. Absorptive Capacity (ACAP) can play a significant role in the value extraction from innovations such as big data analytics (Arunachalam et al., 2017). ACAP can be defined as the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to its commercial ends. The concept is used by many researchers to explain organizational learning from a strategic management perspective. Firms with low absorptive capacity will generally find it difficult to adopt innovative technologies. For a study on the absorptive capacity in supply chains we refer to Gölgeci and Kuivalainen (2020).

Judging how the logistics industry’s innovation capability compares to other industries is a rather subjective matter. Iddris (2016) notes that the measurement of supply chain's innovation capability should help supply chain managers to determine the important innovation areas that need attention most and to permit them to respond to challenges posed by any kind of innovation capability that needs to be enhanced.

TNO (2018) has developed an innovation-adoption model which was designed and tested specifically in the logistics industry setting. The aim of the model is to see how innovations can be accepted by the professionals using the new technology or business concept. This largely depends on the technology readiness, perception of the innovation, the organizational context and individual characteristics (skills) of the professionals. Social innovation is an important aspect in innovation adoption which is very true for implementation of 4C solutions as they imply structural changes of processes and roles within companies.

Consultation with a group of academic supply chain experts in the preparation of this report suggested that generally the innovation capability of the supply chain industry is low compared to other industries. Reasons brought forward were that logistics still is a rather labor-intensive activity, and competition is strong as transport in an open market with relatively low entry barriers and a relatively commoditized product. Therefore, on average the industry sees low profit margins, which reduces its innovation budget.

If this is true, of course this is a particularly important hurdle for innovative concepts such as 4C. And it gives a competitive advantage to other companies vertically integrating into the logistics industry, such as Amazon (see Section 3.5).

5 LITERATURE REVIEW

In this chapter we will go through the fast-growing body of academic literature on collaborative logistics. It is not meant as a full literature review, as this is outside the scope of this 4C synthesis report. Rather, it will be a meta review in which we will point out to some main existing literature reviews. After that, we will discuss a few key subdomains of collaborative logistics in more detail and mention the most prominent publications on these topics.

Overall, academia has given increasing attention to horizontal collaboration in supply chains. A search on sciencedirect.com on papers on ‘horizontal collaboration/collaboration’ and ‘supply chain’ in the period 2000-2019 resulted in the overview of Figure 21. Incidentally or not, the steep rise in published papers per year coincided with the launch of the 4C program in the Netherlands in 2010.

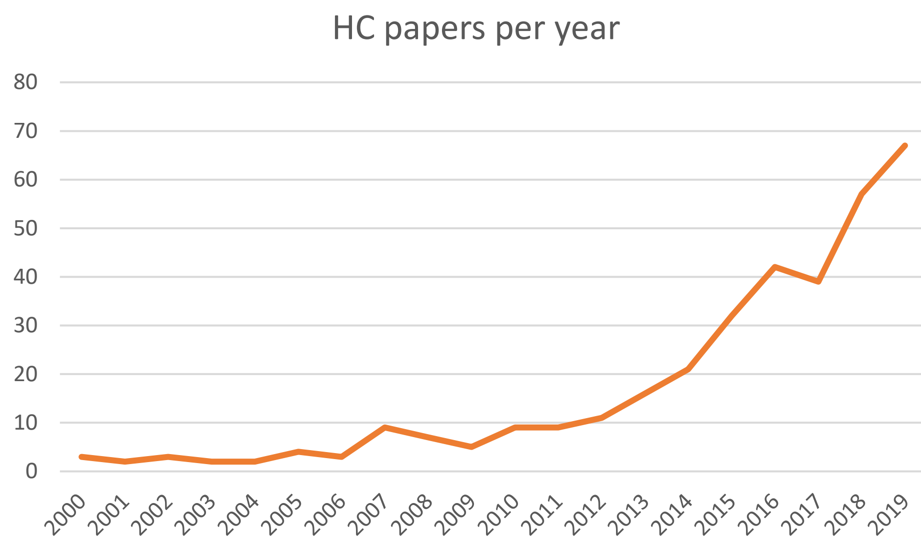

Figure 21. Peer reviewed papers on horizontal collaboration in the period 2000-2019

The growing attention for collaborative logistics in academia is further illustrated by the fact that roughly every five years a new literature review appears, see Table 3. These literature reviews are a great introduction into the topic, and therefore the full references are provided below. The first review by Vos et al. (2002) was conducted as part of an applied research project by TNO and Tilburg University, highlighting the prominent position that the Netherlands take in this field. Also, the second review by Cruijssen et al. (2007) was conducted by Dutch and Flemish researchers. The Flemish team of Verdonck et al. (2013) provided the next literature update, then in Austria Gansterer and Hartl (2018) produced a mostly methodological review and finally to the best of our knowledge latest review was conducted in France, by Pan et al. (2019).

Year	Reference

2002	Vos, B. et al. (2002), SYnergievoordelen in LOGistieke NETwerken (SYLONET), Resultaten van een literatuurinventarisatie, UvT/TNO Inro, Delft. [In Dutch]
2007	Cruijssen, F., Dullaert, W., Fleuren, H., (2007b). Horizontal collaboration in transport and logistics: A literature review. Transportation Journal 46 (3): 22-39.
2013	Verdonck, L., Caris, A., Ramaekers, K., Janssens, G. (2013). Collaborative logistics from the perspective of road transport companies. Transport Reviews 33 (6): 700-719.
2018	Gansterer, M. and R. F. Hartl (2018) Collaborative vehicle routing: A survey. European Journal of Operational Research 268: 1-12
2019	Pan, S., D. Trentesaux, E. Ballot, G Huang (2019) Horizontal collaborative transport: survey of solutions and practical implementation. International Journal of Production Research, 57: 5340-5361

Table 3. Literature reviews on horizontal collaboration in transport and logistics

All literature reviews categorize collaborative logistics into several subtopics. Since these categories differ over the individual reviews, we are forced to make our own selection here as well. The topics we discuss are: 1) Horizontal collaboration from an operations research perspective, 2) Trust, 3) Collaboration actors, 4) Data sharing, 5) Gain sharing and cost allocation, and 6) Legal and Regulatory considerations and 7) synchromodality. But first we will briefly look at the various terms relating to collaborative logistics that can be found in literature.

5.1 Collaborative logistics terminology

Collaborative logistics is a term that can be interpreted in many ways depending on who you talk to and in which context. In the light of 4C, collaborative logistics should have at least an element of *horizontal collaboration*. This does not take away the fact that successful 4Cs will also have strong vertical collaboration elements (i.e. collaboration between buyers and sellers), but the core idea of a 4C is that it combines assets, orders, information etc. horizontally across supply chains.

Mason et al. (2007) and Ferrell et al. (2019) discuss the mix of horizontal and vertical collaboration in collaborative logistics. Collaborative logistics describes the practice where companies work together to improve efficiency in their supply chains rather than operate in isolation and accept the inefficiency that frequently results. Many logistics networks provide opportunities for both vertical and horizontal collaboration. Vertical collaboration occurs when two or more organizations such as a manufacturer, distributor, carrier and retailer share their responsibilities, resources, and performance information in a way that improves overall efficiency. Horizontal collaboration describes relationships between companies performing similar activities or providing similar products that can benefit from economies of scale by working together.

More formally, horizontal logistics collaboration is defined as active collaboration between two or more firms that operate on the same level of the supply chain and perform a comparable logistics function (Cruijssen, 2006), and it provides an interesting optimization area for both shippers and LSPs. The large economic significance of the logistics sector and the problems it is currently facing, contribute to the importance of horizontal collaboration. Increased economies of scale are clearly necessary to prevent the rising transport costs, congestion, and emissions from becoming an even larger burden to welfare than they are at present. Horizontal collaboration seems to be a viable alternative to mergers and acquisitions to attain this increased scale. To illustrate its practical relevance, it is worth noting that in the heavily congested European logistics center of gravity (Belgium and the Netherlands) many horizontal collaborations of various types have already been initiated. Yet, existing literature lacks a general framework to guide practitioners with setting up these collaborations. For sure, not all forms of horizontal collaboration are applicable to any given sector or company. As such, the horizontal collaboration that currently exists may very well not be as effective as it could be. This will be further discussed in Chapter 6.

Horizontal collaboration is discussed in literature using a variety of terms, all strongly connected but with small differences mostly depending on the area of application. The most prominent terms are listed in Table 4.

HC Term	Explanation
4C	4Cs are control centers where the most recent techniques, advanced software concepts and supply chain professionals come together. In a 4C, information flows are coupled to flows of physical goods in an innovative way. By exchanging this information between various entities, a 4C makes it possible to orchestrate across multiple supply chains. See Section 1.2.2 of this report.
Cyber physical systems	A cyber-Physical System (CPS) is a new generation of digital system, which mainly focuses on complex interdependencies and integration between the cyberspace and physical world. A CPS is composed of highly integrated computation, communication, control, and physical elements. See Chen et al. (2017) for a literature review.
Logistics marketplaces	Freight marketplaces match companies looking to ship freight using one or multiple modes of transport (road, air, ocean, and/or rail) with suppliers or brokers of logistics capacity. See Section 3.8 of this report.
Logistics control tower	The basis of the Control Tower is an intelligent software package that is developed to convert large amounts of logistics data into usable information. By collecting and distributing information, the Control Tower is a central information point within one supply chain or between multiple supply chains.
Platform	The proposed concept of the logistic platform is combining the technologies of Internet of Things (IoT) and Blockchain in a new and innovative way. The structure of the platform is a distributed network of nodes which provide or consume different types of services. See Rožman et al. (2019)
General: Collaborative logistics literature interchangeably uses the terms: collaboration, cooperation, partnership, alliance, etc.	

Table 4. Horizontal Collaboration (HC) terms found in literature

5.2 HORIZONTAL COLLABORATION IN OPERATIONS RESEARCH

Operations Research is the field that has produced most papers on collaborative logistics. Gansterer and Hartl (2018) provide and excellent review of this literature. For example, they make the interesting observation that most papers focus on carrier-related collaborations, although they state that from the planning perspective it does not matter whether carriers or shippers oversee the process. However, in decentralized collaboration settings the issue of information asymmetries must be considered as shippers and carriers typically do not have the same level of information. They therefore explicitly distinguish whether carriers or shippers are the players in a collaboration. The authors also state that collaborative vehicle routing is an active research area of high practical importance and they continue by identifying three major streams of research, which are 1) centralized planning, 2) non-auction-based decentralized planning, and 3) auction-based decentralized planning. Literature was further classified based on the underlying planning problem and the collaboration setting, see Table 5).

	Decentralized planning	
Centralized planning	**Without auctions**	**With auctions**
Gain assessment	Partner selection	Request selection
Methodological contributions	Request selection	Winner determination
	Request exchange	Profit sharing

Table 5. Research topics categorized by Gansterer and Hartl (2018)

Looking a bit closer at the extensively studied topic of auctioning, Berger and Bierwirth (2010) have proposed the standard auctioning process among carriers bidding for a transport request:

1. Carriers decide which requests to put into the auction pool.
2. The auctioneer generates bundles of requests and offers them to the carriers.
3. Carriers place their bids for the offered bundles.
4. Winner Determination Problem: Auctioneer allocates bundles to carriers based on their bids.
5. Profit sharing: collected profits are distributed among the carriers.

The question whether central of decentral planning is most suitable for collaborative logistics is also discussed by the PhD thesis of Huijink (2016). He summarizes his findings in the following overview.

	Information sharing	**Decision freedom**	**Computational complexity**	**Decision dependency**
Central planning	High	Low	High	High
Auction based	Medium	High	Medium	High
Price base	Low	Medium	Low	Low

Table 6. Comparison of different collaboration types (Huijink, 2016)

As a general observation, it is striking to see that in scientific literature, much attention is quite given to specific (methodological) elements as surveyed by Gansterer and Hartl (2018), but very few publications focus on the organizational and business model aspects. Likewise, most attention is given to short-term collaboration (auctions) instead of more longer-term collaboration under a 4C-like setup.

5.3 TRUST AND COMMITMENT

Trust is a vital facilitator for collaboration. Relying on a partner that in principle has other objectives is a risky undertaking, and therefore trust is necessary to reach a stable form of collaboration. Commitment is closely related to trust and refers to the bond between companies in a collaboration. Rindfleish (2000) discusses the differences in trust between vertical and horizontal collaboration. The main observation is that resource-dependence is lower for horizontal collaboration because these partners do not depend on each other to acquire their necessary inputs. Moreover, the competitive element in horizontal collaboration increases the threat of opportunism and lowers the level of trust, because one participant may use information gathered in the collaboration to improve its market position at the expense of other participants. Therefore, trust alone is not a suitable governance mechanism for horizontal collaboration. Instead it is advisable to construct a set of collaboration rules, partially replacing trust with control as a governance mechanism. An elaborate discussion of both trust and control in collaborations can be found in Das and Teng (1998). There are some situation-specific factors that may increase mutual trust in horizontal collaboration, such as the presence of shared customers (cf. Lambert et al., 1999). Finally, horizontal collaborations are likely to originate from more institutional and interpersonal connections (e.g. social contacts, sector associations etc.) than vertical collaborations. These connections can make up for the difficulties produced by initially low levels of trust, commitment, and dependence

Trusts manifests itself at inter-personal, inter-group, inter-organizational and inter-network levels. All of these should be carefully considered to make a collaboration work (Lascaux, 2020). This is especially important when collaboration takes place between competitors. In such cases, the interaction between the collaborators is referred to as *Co-opetition*, which is a whole research area on its own. Coopetitive interfirm relationships differ from the patterns of collaboration between non-rival partners on several important aspects. Based on Bengtsson and Kock (2000), collaboration between competing firms is marked by inevitable tensions generated by the conflicts between (1) cooperative intent in a jointly run project and inter-partner rivalry in the broader market, (2) collective efforts to create value in a partnership and competitive attempts at capturing the outcomes of collaboration, (3) the need to invest intellectual resources into common activities and the necessity to protect the firm's knowledge and other intangible assets from appropriation by rivals.

Concerning interfirm knowledge exchange in coopetition, Cheng et al. (2008) have established that trust has a positive impact on interorganizational knowledge sharing in coopetitive supply chains, and that the more a certain factor enhances trust (such as active participation and regular communication) or diminishes it (such as opportunistic behavior), the bigger its corresponding influence on commitment to the collaborative project.

From the practical side, VIL (2005) conducted a survey among logistics practitioners about the role of trust in logistics collaborations. They suggested the following guidelines to increase trust among partners:

- Share information pro-actively
- Be reliable and act consistently
- Formulate clear and realistic expectations
- Document all agreements
- Use a trusted external intermediary
- Work under clear rules of engagement

5.4 COLLABORATION ACTORS

To make collaborative logistics work under a 4C, the minimum actors that are needed obviously are multiple shippers and multiple LSPs. But the success of a collaboration can be strongly increased if also some other (mediating) actors are actively involved. In their report TNO (2005) list the relevant actors in projects that focus on collaboration among shippers. These actors and their main roles in a (4C) collaboration project are summarized in Table 7.

Actor	**Description**
Customers	Mostly it is important that customers are informed and aware of the collaboration project. In theory, customers should benefit from it by improved service. In some cases, active involvement of customers is needed, for example when changes are needed in delivery days or quantities. In such cases, customers must be included in the project team.
LSPs	Even if collaboration takes place among shippers, active involvement of one or more (new or incumbent) LSPs is necessary (See also Chapter 9). LSPs are the ones with experience in implementing logistics changes and innovations and will become more and more important when the project moves from the design to the execution phase.
Suppliers	Suppliers have a similar role as the customers discussed above. In case of collaboration on inbound logistics, they will have an important role to play in facilitating the collaboration.
Advisors and knowledge institutes	On a high level, advisors and knowledge institutes have two possible roles to play: as a support role (matchmaking, calculation of benefits, gain sharing, legal arrangements, etc.), but also as a day-to-day organizer of the project, especially in the start-up phase.
Independent arbitrator	It can be valuable to hire a specialized independent third party to act as an arbitrator, for example in case of disputes or to motivate the consortium to stay committed to the goal of the project.
Industry organization	Industry organizations can play a meaningful role in the matchmaking and partner selection phases of a collaboration project, and as a platform to share knowledge and experience.
Governments	Government policies such as 4C are very much in line with the objectives of a horizontal collaboration project. Providing subsidies for the start-up of a project or possibly modifying legislation that is hampering its success are possible support actions.

Table 7. Actors in horizontal shipper collaboration projects (TNO, 2005)

The concept of the independent arbitrator (later called a 'trustee') mentioned in Table 7, was further established in Cruijssen (2012). He stated that there is a need for a specialized entity to design, develop and manage a collaboration. If such a neutral, transparent, and trusted party is not present, there would be a severe risk that not all parties will efficiently work together in the long run on a fair give and take basis. This concept of a *trustee* is still a rather new concept in logistics and not much can be found in literature about the specific role of a trustee in horizontal collaboration. Nonetheless, a trustee can be crucial when setting up a collaboration. For example, in the startup phase providing information to the other participants could be undesirable, especially when the participating companies are competitors. A trustee can solve this issue. All information would be sent to the trustee, who can then determine whether there is a positive business case or not. In this way the company specific information of the participating companies is not available to all the other participants. The trustee function is usually executed by a specialized consultant, but this can also be a lawyer, an industry group or a trade association.

Typically, there are two separate types of collaboration support activities carried out by a trustee, see Table 8. We categorize these types as 'offline' and 'online' activities. The offline function requires the trustee to play an external, supporting role and as such will not take part in the day-to-day operations, activities, or processes of the collaboration. The online function in turn requires a trustee to be a pivotal actor in the horizontal community on a day-to-day basis and to be responsible for the harmonious organization of operations. These two separate tasks may require that the trustee function be divided over two separate legal entities.

Online functions	**Explanation**
Loads combination	A trustee should be able to fully support a company's in reducing inventory and work to a tighter just-in-time system shipping regular small quantities on tight lead times. The trustee must keep these small shipments cost effective by combining them into bigger consolidated shipments.
Prioritization	The trustee should be completely neutral in its prioritization of jobs coming from the various partners. It must do so according to decision rules that were formulated in the setup phase of the collaboration, and that ideally are formalized in the contract.
Synchronization	The trustee is responsible for maximizing the possibilities of order synchronization. It must perform a signaling function that makes shippers aware that cost reduction through bundling can be achieved if their shipments are somewhat delayed or released earlier.
Contact person	The trustee is always available as a contact person for all collaborators, both for LSPs and shippers. It also provides a neutral platform and safe location for meetings, brainstorms, and discussions.
Interfaces	The trustee is responsible for the definition and implementation of interfaces between the IT systems of the various partners.
Matching	The trustee makes sure that LSPs are selected that correctly match the transport needs of participating shippers.
Offline function	**Explanation**
Critical mass	The trustee is always searching for the best transport flows and capacities to further extend and improve the collaboration. This involves new partner

	selection and the increase of the flows managed by the collaboration within the current group of participating companies.
Stability and gain sharing	The trustee safeguards stability of the collaboration by ensuring correct gain sharing.
Legal compliance	Trustee makes sure that the collaboration is fully legally compliant.
Entry and exit	The trustee makes sure that the collaboration is flexible enough to cope with changes in the composition of its partners, being either LSPs or shippers.
Conflict resolution	In cases of conflict, the trustee will be the first to act as a referee.
Satisfaction	Though difficult to formalize, the trustee makes sure that all partners are satisfied with the course of the collaboration.
Confidentiality	The trustee prevents potential partners from having to share data directly, which may be against competition law (see legal section under tools and technology).

Table 8. Offline and online functions of a trustee

5.5 DATA SHARING

To enable effective supply chains, the overall information systems architecture must be capable of linking or coordinating the information systems of the individual parties into a cohesive whole. Gansterer et al. (2020) argue that given the tightening efficiency pressure in logistics, mechanisms to benefit from idle capacities are on the rise. In this sharing economy, collaboration is a key concept. They assess the benefit of sharing information in (auction-based) carrier collaborations where carriers seek to exchange transport requests to decrease mileage and increase vehicle utilization. Even though carriers are unlikely to share sensitive or business-critical information, they may be willing to share non-sensitive and non-critical information if it increases their profit. A separation between these two levels of data is required.

Each company's information system should support the management of both proprietary and shared or open data. The proprietary data would be accessible only to those employees who have legitimate internal business needs. The shared data should be available through appropriate information interfaces to customers, logistics suppliers, or any other party having a need to know, through a contract or standard to which all parties agree. This has become more important as many companies are increasingly outsourcing their logistical activities to third parties, (Stefansson, 2002). Data sharing between parties in the supply chain is of fundamental interest, since correct and complete information is essential for carrying out an effective and efficient movement of consignments, and this is obviously even more true in the case of horizontal collaboration or 4C. Below we discuss two types of data that can be shared; operational and tactical/strategic data.

5.5.1 Operational data sharing and blockchain

As stated by Lee and Whang (2000) on a high level there are three methods for data sharing: 1) direct information transfer, 2) third party processing, and 3) a central information hub. In the light of today, the first option seems preferable. The use of *blockchains* has the potential to enable transparent and trustworthy documentation of events in a supply chain where multiple organizations are involved, and where no entity should be able to manipulate information without it being noticed. An overview of the use of blockchain technology in the supply chains can be found in Helo and Hao (2019). Achieving the same level of transparency when using centralized databases requires quite different auditing mechanisms and it is questionable whether this is feasible in a global setting (Sund et al, 2020).

It is argued by Rožman et al. (2019) that as more and more parts of the supply chain are being equipped with IoT devices and the future of the supply chain is moving towards fully automated processes such as the Physical Internet, LSPs start to digitalize their services to connect to the Internet at any given time. IoT has an important role in closing the gap between physical and virtual worlds and automation of the supply chain has already made a huge step through this technology. Implemented technology of the IoT in the supply chain enables a stream of real time information about the current state of single components from anywhere in the world. So far, these streams of information were only stored in big data centers or clouds, but the data was not commonly used for analytics and system improvement. With Blockchain, supply chain managers are finding new ways to incorporate and optimize their supply chain. Many believe that Blockchain serves as a missing piece to the puzzle of IoT, as it enables agreements between two parties without the intermediate party. Therefore, two smart devices from opposing parties can make an agreement in the form of a smart contract which is not susceptible to corruption and scams. Microtransactions between smart devices in an extremely safe manner are now possible and can be executed without human interference, thereby strongly facilitating data exchange, also in complex collaboration such as a 4C.

5.5.2 Tactical/strategic data sharing

Whereas the combination of IoT and blockchain may prove a solution to operationalize future supply chain collaboration horizontally and vertically, it is not a solution for companies wishing to engage in horizontal collaboration today. Unfortunately, there is still quite some manual labor to do to make horizontal collaboration work. Static logistics data extracts are requested from companies that have expressed an interest in horizontal collaboration. Supply network collaboration and coordination rely on capabilities to share, transform, and use data among all the collaborating partners. Several standards and ICT solutions are available to this purpose, yet these are far from being widespread in the logistics industry community.

EU funded projects like CO3, Nextrust and Logistar (See Section 7) all have invested heavily in gathering representative datasets from industry to test their collaborative innovations. Often, this data gathering was a difficult and time-consuming exercise that was not always successful. In fact, data becomes more valuable due to improved data mining techniques and companies are ever less inclined to share them without complete insurance that they will not be used for unwanted purposes. Therefore, there is a need for clear and standardized rules for data sharing and ownership. It is interesting to mention here the Dutch initiative of iSHARE[16] that ambitions just that. iSHARE is a set of agreements that enables organizations to give each other access to their data. Since they all work with the same identification, authentication, and authorization methods, they do not need to make new agreements every time they want to share data.

[16] https://www.ishareworks.org/en/ishare/what-ishare

Together, the Participants in the iSHARE scheme can share data effortlessly. In this context, 'effortlessly' means that Participants in the iSHARE scheme:

- Do not need costly and time-consuming integrations to share data.
- Can share data with new and previously unknown partners.
- Always maintain full control over their own data.

This may very well be a good intermediate development for data sharing towards the blockchain enabled Physical Internet. But in the meantime it is recognized that to achieve a step-change in transport efficiency through collaboration it is still necessary to collect, on a regular basis, large amounts of transport data from companies wishing to participate in the initiative.

The Logistar project (Palmer et al, 2019) identifies the following data elements for the most recent full calendar year as necessary for a good 'collaboration profile' of a company to be used for the assessment of collaboration potential. Fields marked with (*) were the minimum needed to analyze a network. Other fields were optional. These companies all used LSP's for their transport movements.

- Origin address = city, postcode, country (*)
- Destination address = city, postcode, country (*)
- Customer ship-to name (*)
- Customer sold-to name
- Order reference
- Transport mode(s) (*)
- Vehicle or unit type (tautliner, container, reefer…)
- Transport date (*)
- Delivery time windows
- Product type (general cargo or ADR)
- Shipment size (pallets, load meters and/or kgs) (*)
- Shipment cost (can often also be deduced from contractual price matrices)
- Name of transport company or hauler

As the Logistar project experiences, like many other projects, it is not always possible to collect all data elements from every possible collaboration partner. Figure 22 illustrates this in a bit more detail. The more detailed data are gathered the better the assessment of collaboration potential will be. However, it will also make it more difficult and time-consuming to gather all this data. This trade-off needs to be made in every collaboration project until there will be an industry-wide standard for trustworthy data sharing.

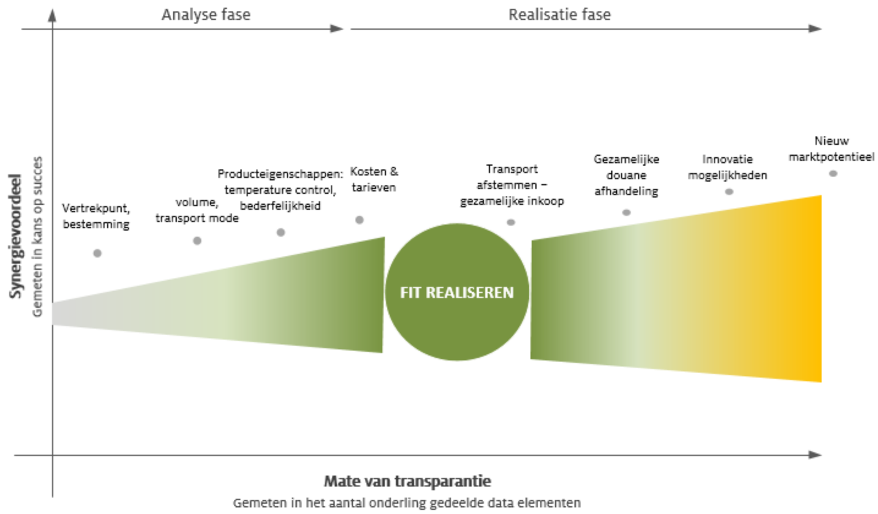

Figure 22. Data richness and synergy assessment [In Dutch]

5.6 GAIN SHARING AND COST ALLOCATION

The sharing of costs and benefits is perhaps the most studied topic in the collaborative logistics field. So much so, that Guajardo and Rönnqvist (2016) prepared a separate literature review of the topic, covering 55 papers. Indeed, cost and gain sharing is an important topic. Mistrust about the fairness of the applied allocation rule for savings has caused many horizontal logistics collaboration initiatives between shippers, and/or LSPs to marginalize, disintegrate or even fail to start (Cruijssen, 2006). The area is expanding rapidly and Guajardo and Rönnqvist (2016) identify more than 40 cost allocation methods. These can be categorized in game-theoretical rules and ad-hoc or proportional rules. A simple approach for cost allocation is to use a proportional allocation that can be based on the overall volume or weight of the products transported. The more advanced approach is to use principles based on cooperative game theory.

5.6.1 Proportional rules

Most often, allocation rules are simple rules of thumb that distribute savings proportionally to a single indicator of either size or contribution to the synergy, such as the total load shipped, the number of customers served, the logistics costs before the collaboration, the distance travelled for each shipper's orders, the number of orders, the number of drop-off points, etc.

Because these rules are easy and transparent, they are likely to appeal to practitioners initially. However, when using a single construct, the others are obviously disregarded. For example, if gain sharing takes place according to the number of drop points of each participant, a certain partner who delivers a large number of drop points in a small geographical region will get a large share of the benefits, while his de facto contribution to the attained synergy is negligible if the other participants serve only few drop points in this area (Cruijssen et al., 2010). Özener and Ergun (2008) confirm this by stating that the often-used proportional allocation rules have several drawbacks, particularly in terms of stability. Using such a cost allocation method may result in a break-up of the collaboration. In fact, they find that for proportional cost allocations approximately 25% of all tested instances become instable, which suggests that there exists a significant risk for the disintegration of the collaboration.

5.6.2 Game theoretical rules

Cooperative game theory focuses on cooperative behavior by analyzing and simulating the negotiation process within a group of companies in establishing a contract. This includes an allocation of collaboratively generated revenues or collaboratively avoided cost. In particular, the possible levels of collaboration and the revenues of each possible coalition (i.e., a subgroup of the consortium) are considered to allow for a better comparison of each company's role and impact on the group. In this way, companies in a coalition can settle on a compromise allocation in an objectively justifiable way.

The Shapley value (Shapley, 1953) is a well-known solution concept that allocates synergetic effects based on several important and objective fairness properties. Below we will briefly discuss five of these properties that are useful in the context of horizontal logistics collaboration:

1. **Efficiency**. This property value ensures that the total value of the grand coalition is distributed among the partners, i.e., no value is lost.
2. **Symmetry**. Two partners that create the same additional value to any coalition receive the same share of the total value.
3. **Dummy**. Partners that do not contribute anything to any coalition except their individual value indeed receive exactly their individual value as a final share of the total value.
4. **Strong monotonicity**. This guarantees that if all the partner's marginal contributions increase, his payoff will increase.
5. **Individual rationality**. A partner will be better off in the collaboration than alone.

It has been proven that the Shapley value is the unique solution concept that satisfies all these five properties (Shapley, 1953).

The Nucleolus was developed by Schmeidler (1969). The nucleolus satisfies the properties of efficiency, individually rationality, symmetry, and dummy. Moreover, if a stable allocation exists (i.e., no coalition has an incentive to leave the grand coalition), the nucleolus will give a stable allocation. This is not necessarily true for the Shapley value. The nucleolus however is even more difficult to compute than the Shapley value. For larger groups of collaborators though, this calculation becomes very time intensive.

In Tijs and Driessen (1986), cost allocation methods are presented, based on the notion that the total cost to be allocated is divided into two parts: the separable and the non-separable costs (SNS). Methods based on this idea first allocate to each participant his separable cost, then distribute the non-separable cost among the participants according to given weights. The separable cost of a partner is equal to the cost level of the whole group minus the cost level of the whole group, excluding this partner (Frisk et al., 2010). The distribution of the non-separable cost can take place in various ways using different weights for the participants. This rule will satisfy the efficiency and symmetry property. If carefully chosen, the allocation rule will also satisfy the individual rationality and dummy property. As such, it is a useful approximation of the Shapley value with the virtue that it is can be calculated much easier.

The equal profit method (EPM) is developed by Frisk et al. (2010) to cover for some disadvantages in the allocation models discussed above that are based on their experience with the acceptance of these rules by companies in practice. They found that companies were mostly interested in the relative savings they incurred individually compared to their baseline cost, i.e. without collaboration. The developed Equal Profit Method aims to minimize the maximum difference in pairwise relative savings. These differences are calculated for each of the N(N-1) distinct pairs of participants, and minimized by choosing the most suitable allocation, while also satisfying the stability constraint if possible. This rule will work quite well for groups of comparable partners, but it is very sensible to free riding. A dummy player will get assigned the same relative savings as the partner that brings in the most synergetic flows.

Table 9 shows the formal properties of these rules and our subjective assessment of the ease of implementation. From this table we conclude that proportional rules and the Nucleolus have important drawbacks, for the nucleolus this is its complexity, which makes it difficult to have practitioners understand and trust it. This drawback could become smaller in the future, when the concept of collaboration is more established and trustees are really trusted in their advice for gain sharing, also when they apply the nucleolus. From the table we conclude that the Shapley value and the SNS methods are preferable. The Shapley value should be used for smaller, coherent groups. The SNS method is very suitable for dynamic collaborations of changing partners.

	Proportional	**Shapley**	**Nucleolus**	**SNS**	**EPM**
Monotonicity	☒	☑	☒	☒	☒
Dummy	☒	☑	☑	☑	☒
Efficiency	☑	☑	☑	☑	☑
Individual rationality	☒	☑	☑	☑	☑
Symmetry	☒	☑	☑	☑	☒
Ease of implementation	☑	☑/☒	☒	☑	☑

Table 9. Properties of gain sharing mechanisms

5.6.3 Stability

Tinoco et al. (2017) show that the stability (and thus the long-term viability) of the partnership strongly depends on the allocation mechanism used to share the costs and gains. A collaboration consortium is dynamic almost by definition: unlike in vertical supply chain collaborations, there is no strict commercial governance structure of buyers and sellers. In contrast, every partner will make an assessment every once in a while, whether it will stay in the consortium or not. A well-constructed gain sharing mechanism can ensure stability of the consortium, but only if every participant provides enough synergy to the group. If for example participant X has a changed customer base or has other changes in its logistics operation, it is for example possible that the group can attain a bigger synergy without X than with X. In such a case the group will wish to ask company X to leave.

5.7 LEGAL AND REGULATORY CONSIDERATIONS

Many papers on collaborative logistics indicate that a solid legal basis for collaboration is crucial. A comprehensive legal framework is developed in two European projects: CO3 and Nextrust. Below, based on Cruijssen (2010) and Biermasz (2012), we discuss the two most cited legal hurdles, i.e. the underlying contracts and the role of competition law.

5.7.1 Contracts

The table below summarizes the most important documents to be incorporated in a legal framework for logistics collaboration, i.e. a standard/model contract, general terms and conditions for collaboration, a service level agreement, a non-disclosure agreement and a letter of intent.

Standard contract	The standard contract contains the core obligations that the contract partners agree on, such as service and payments. In the contract, all operational and organizational aspects should be included.
Terms and conditions	Terms and conditions contain terms that hold for all partners that are possible participants to the project. The more elaborate the terms and conditions, the simpler the final contract can be. This is certainly advisable to avoid lengthy individual contract negotiations.
Service level agreement	This offers the starting points for the daily execution of the consolidated flows. The legal significance only exists in conjunction with the contract. It is typically a technical logistics document.
Non-disclosure agreement	This document details the obligation to treat information of the participants confidentially.
Letter of intent	Contains the formal intent of potential participants to enter negotiations with the goal to close a contract to collaborate. Usually, a letter of intent does not hold any legal guarantees, but it communicates commitment of the parties.

Table 10. Contracts used in horizontal collaboration projects

5.7.2 Competition law

Sharing of information between direct competitors can be problematic from a legal perspective if there is a danger of either collusion or market protection. Collusion happens when competitors together can concert their competitive practices (or to control who deviates) and as such limit competition in the marketplace at the expense of the end customer. Market protection is a situation where the group of collaborating companies would prohibit other competing companies to take part in the partnership and thereby creating a competitive disadvantage.

Whether in practice a collaboration is legal or not strongly depends on the circumstances. Obviously, there is a tradeoff between the positive element from collaboration that efficiency rises and the impact of transport on the environment will become less as a result, and the negative element of the threat of a reduction of competition at the expense of the end customer. In specific cases, a court might order a proportionality check to see if the same advantages could not have been reached with less restrictive measures by the partners. Although generic rules do not yet exist, some rules of thumb can be formulated, see Table 11.

Topic	**Explanation**
Transparency	The more transparent the market in which the collaboration takes place, the more difficult the collaboration will be under competition law.
Consortium size	The fewer and bigger the participants, the more difficult the collaboration will be under competition law.
Stability	The more stable and predictable the collaboration is, the more difficult it will be under competition law.
Strategicness of data	Strategic data, such as prices, cost levels, customer bases, costs, marketing plans etc., are extremely sensitive under competition law.
Recentness of data	More recent data are always more sensitive than older data. Information about future actions in the future are very tricky to share under competition law.
Market share	The larger the market share of the group of collaborators, the more difficult the collaboration will be under competition law.
Frequency of information exchange	The more frequent a data exchange is, the more difficult the collaboration will be under competition law.
Openness	The more difficult it is to acquire the same data in the open space, the more difficult the collaboration will be under competition law.
Anonymization	Exchange of company-specific data will lead to problems more quickly. The harder it is to track data back to information of a competitor, the safer the collaboration is from a competition law point of view.

Table 11 Rules of thumb for competition law obeyance under horizontal collaboration

Exact rules do not exist, so competition law aspects are a rather grey zone, but the current interpretation by many companies is that collaboration between companies is allowed if it does not interfere with the overall market dynamics. Point of departure here is that competition law may indeed prohibit horizontal collaboration in the same manner as a cartel does. The cartel ban is included in article 101 paragraph 1 of the Treaty on the Functioning of the European Union:

The following shall be prohibited as incompatible with the internal market: all agreements between undertakings, decisions by associations of undertakings and concerted practices which may affect trade between Member States and which have as their object or effect the prevention, restriction or distortion of competition within the internal market, and in particular those which:

- directly or indirectly fix purchase or selling prices or any trading conditions.
- limit or control productions, markets, technical development, or investment.
- share markets or sources of supply.
- apply dissimilar conditions to equivalent transactions with other trading parties, thereby displacing them at a competitive disadvantage.
- make the conclusion of contracts subject to acceptance by the other parties of supplementary obligations which, by their nature or according to commercial usage, have no connection with the subject of such contracts.

However, this prohibition has exemptions if it can be proven that the agreement 1) improves production processes, 2) improves distribution, or 3) improve technical of economic progress. It is to the collaborating consortium to prove that they in fact qualify for one or more of these conditions. There is no formal regulation or jurisdiction here yet, but specialized lawyers expect that such collaborations will be allowed if the total market share of the consortium is less than 30%[17].

5.8 SYNCHROMODALITY

The final collaboration topic that we discuss in this chapter is the recently developed concept or synchromodality. Pfoser et al. (2016) defined Synchromodality as an *'evolution of inter- and co-modal transport concepts, where stakeholders of the transport chain actively interact within a collaborative network to flexibly plan transport processes and to be able to switch in real-time between transport modes tailored to available resources. The shipper determines in advance only basic requirements of the transport such as costs, duration, and sustainability aspects. Thus, transport processes can be optimized, and available resources sustainably and fully utilized'*. Synchromodality can go hand in hand with a 4C concept. In fact, next to 4C, synchromodality was also one of main research domains identified and funded by the Dutch government through their 'Top-sector policy' (See Section 8.2). If a 4C gets the freedom by a shipper to pick the most beneficial mode of transport depending on actual real-time availability, prices, timings, etc. the 4C get much more freedom to leverage its broader view across supply chains to further increase efficiency.

Giusti et al (2019) argue that the most important characteristics of synchromodal logistics that allow smarter utilization of available resources are real-time information, flexibility, collaboration and coordination, and synchronization. Real-time information is essential for synchromodal logistics. In fact, the other features rely strongly on it. Ideally, in a synchromodal supply chain, stakeholders should be able to have a global view of their activity status and events affecting them. With this knowledge, it is possible to adopt effective re-planning procedures and react immediately to unexpected events. Flexibility by customers that relax certain constraints for their shipments, gives more optimization freedom to LSPs. For instance, a-modal booking implies that customers do not beforehand select modes and routes for their shipments. This allows LSPs to optimize the available capacities and to react effectively when disruptions

[17] How this 'market' is defined and restricted is an important question still.

occur by automatically switching modes or prioritizing shipments. The more freedom is given to LSPs, the more efficiently they can react to disruptions.

Collaboration and coordination are fundamental for a synchromodal network. Collaboration requires the integration of stakeholders' networks to improve consolidation of flows and to increase the overall capacity. As highlighted by Tavasszy et al. (2017), while vertical integration is often central in inter-modality studies, horizontal integration is especially important in synchromodality.

Now that the most important insights from horizontal collaboration literature have been discussed, we are now ready to take a closer look at actual collaboration projects and concepts. In the next chapter we will discuss and elaborate on the existing literature on horizontal collaboration typologies.

6 CROSS-CHAIN COLLABORATION TYPOLOGY

In the previous chapter we have discussed the most important literature that is needed to understand the theoretical rationale behind the 4C concept. In this chapter we will take a first step towards practical implementations of 4C by reviewing typologies of horizontal collaboration initiatives in literature. Once categorized, commercial collaboration initiatives form a particularly useful base to learn from when setting up new collaborations. With this goal in mind, next to the formal typologies, we will close this chapter with several more qualitative recommendations for the successful management of horizontal collaboration. In the chapters following this typology chapter, we will continue our journey from theory to practice: from a summary of (European) applied research projects, via learnings from Dutch collaboration projects, to recommendations to policy makers, academia and commercial companies wishing to set up a logistics collaboration consortium.

6.1 REVIEW OF EXISTING HORIZONTAL COLLABORATION TYPOLOGIES

Horizontal logistics collaborations come in many shapes in practice. To learn from the experiences and to understand which setups succeed and which ones tend not to succeed, a typology for horizontal collaboration is required. In literature, several structured descriptions of (horizontal) collaboration projects can be found. In this section we describe the most relevant ones.

First, we must explain what we mean by a typology. We define it as *a scheme of the most relevant aspects of horizontal collaboration initiatives, where possible accompanied by a scale on which these aspects can be scored*[18].

A typology is useful for various reasons. First, it can be used as a design tool for new initiatives, making sure that all important aspects are carefully considered. Second, it enables finding 'similar' initiatives that can be benchmarked against each other and among which information and experiences can be shared. Third, a typology is a structuring tool that can help to understand which types of collaboration projects have the highest probability of success. Finally, a clearly structured typology can be useful to come up with project setups (combinations of various typology elements) that have not yet been tested in practice.

Considerable academic attention has been given to the various types of horizontal collaboration that are observed in practice and/or conceptually possible in theory. In the subsections below we discuss the ones that are most relevant for the topic of 4C.

6.1.1 Lambert et al. (1999)

Lambert et al. (1999) identify three types of collaboration depending on the level of integration of partners (see Figure 23). Although this categorization was initially designed for vertical supply chain relationships,

[18] Other terms that have similar goals to this are: classification, taxonomy, categories, framework, etc. In this report we stick to the term typology.

it can straightforwardly be translated to accommodate horizontal collaboration. This spectrum is demarcated on the left-hand side by *Arm's length collaboration*, and on the right-hand side by *Horizontal integration*, which are not considered to be genuine horizontal collaboration. However, it can be stated that horizontal integration, or a merger, is in fact an extreme case of horizontal collaboration.

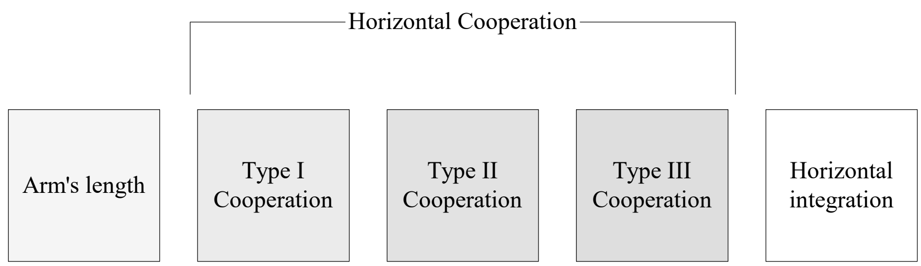

Figure 23. Horizontal collaboration and the level of integration (inspired by Lambert et al., 1999)

In an arm's length collaboration, communication is of an incidental nature and companies may collaborate over a short period of time, involving only a limited number of exchanges. There is hardly a sense of joint commitment or joint operations. An example in the logistics industry is if one LSP subcontracts a comparable LSP in the event of a capacity shortage.

A *Type I* collaboration consists of mutually recognized partners that coordinate their activities and planning, though to a limited degree. The time horizon is short-term, and the collaboration involves only a single activity or division of each partner company. *Type II* is a collaboration in which the participants not merely coordinate, but also integrate part of their business planning. The horizon is of a long though finite length and multiple divisions or functions of the companies are involved. In *Type III* collaborations, the participants have integrated their operations to a significant degree and each company regards the other(s) as an extension of itself. Typically, there is no fixed end date for such a collaboration. Type III collaborations are often referred to in literature as *strategic alliances*. Table 12 describes the three types identified by Lambert et al. (1999).

Relationship	**Description**	**Example**
Type I	The organizations involved recognize each other as partners and, on a limited basis, coordinate activities and planning. The partnership usually has a short-term focus and involves one division within each organization.	Data exchange Joint distribution or linehaul Back loading Purchasing/tendering group
Type II	Although not expected to last 'forever' the partnership has a long-term horizon. Multiple divisions within the firm are involved in the partnership.	Synchronized planning Multimodal collaboration Warehouse/cross dock sharing

Type III	The organizations share a significant level of integration. Each party views the other as an extension of their own firm.	Network integration Joint investments

Table 12: Types of relationships (Lambert et al., 1999)

6.1.2 Cruijssen (2006)

The first typology specifically focusing on horizontal collaboration was proposed by Cruijssen (2006). The paper identified four main discriminating characteristics of collaboration initiatives:

- Decision level (operational, tactical, or strategic)
- Competitive or non-competitive,
- Assets shared (orders, logistics facilities, rolling stock, market power, supporting processes, and expertise)
- Objectives (cost reduction, growth, innovation, quick response, and social relevance)

Based on these four dimensions the then known types of horizontal collaboration were universally described, not per practical implementation, see Table 13.

	O/T/S	C/NC	OR	LF	RS	MP	SP	E	CR	G	I	QR	SR
Lobbying group	S	C				◕		◔	◑	●	◑	◑	◑
Maintenance group	O	C/NC		◔	◑	◔	●	◔	◑				
Purchasing group	O	C/NC			◔	●	◕	◑	●		◔		◔
Chartering	O/T	C	◕		◕				◔	◑			
Warehouse sharing	O/T	C/NC	◑	●	◕				◑	◑	◔		◔
Freight sharing	O/T	C	●			◔			◕	◑			●
Knowledge centre	S	C				◔	◑	●		◑	◑	●	◔
Road assistance	O	C			●		◕		◔				◑
Co-branding	S	C/NC				●	◑	◔		◔	●	◔	
Tendergroup	T/S	C		◔	◑	◕		◑			◕		
Asset pooling	O/T	C	◔	●	●	◔			◑	◑			◑
Intermodal group	S	NC	●	◔	◑	◔		◔	◔	◔	◑	◔	●
Shared crossdock	T	C/NC	◕	●					◑				◔
…													

O	Operational	MP	Market power
T	Tactical	SP	Supporting processes
S	Strategic	E	Expertise
C	Competitive	CR	Cost reduction
NC	Non-competitive	G	Growth
OR	Orders	I	Innovation
LF	Logistics facilities	QR	Quick response
RS	Rolling stock	SR	Social relevance

Table 13. Typology by Cruijssen (2006)

6.1.3 Leitner et al. (2011)

The next typology of horizontal collaboration came five years later by Leitner et al. (2011). They argue that many collaboration approaches fail due to insufficient targets and insufficient organizational involvement. Therefore, the definition of organizational aspects as well as forms and specifications of collaboration models are needed to guarantee sustainable success of horizontal collaborations.

This motivated the development of the framework depicted in Figure 24. The two discriminating dimensions they consider are collaboration level (or: intensity) and the potential of consolidation. Using these two dimensions they map four collaboration situations in order of increasing level and potential: 1) no collaboration, 2) purchasing collaboration, 3) transport collaboration, and 4) supply chain collaboration.

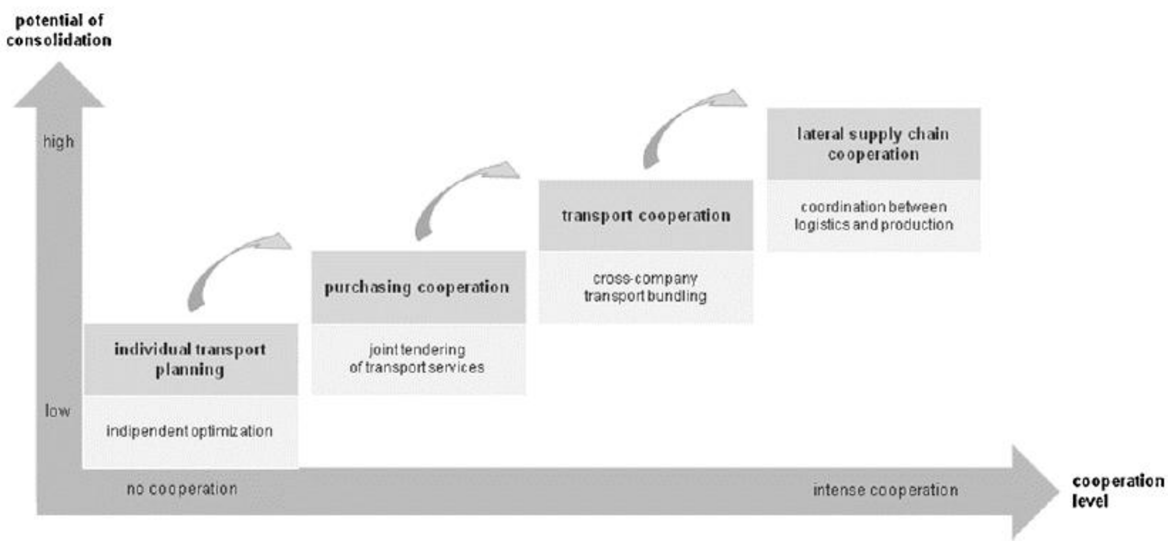

Figure 24. Framework for horizontal logistics collaboration by Leitner et al. (2011)

6.1.4 Schmoltzi and Wallenburg (2011)

A more detailed typology is offered by Schmoltzi and Wallenburg, also in 2011. They introduce a typology based on six dimensions for which, like the approach used by Cruijssen et al. (2006), they then provide the possible values. This typology is summarized in Figure 25, which they refer to as the 'logistics collaboration landscape'.

Contractual scope	Unwritten agreement	Contractual agreement	Minority stake agreement	Joint venture agreement		
Organizational scope	Bilateral	Multilateral				
Functional scope	Shared production	Shared marketing and sales	Shared supply	Quasi-concentration		
Geographical scope	Regional	Nationwide	Continental	Intercontinental		
Service scope	Road services	Rail services	Sea services	Air services	Intermodal services	Value-added services
Resource scope	No resource similarity	Similar market competence	Similar market penetration	Similar corporate structure	Extended resource similarity	

Figure 25. The logistics collaboration landscape (Schmoltzi and Wallenburg, 2011)

The goal is that this typology will help logistics managers to position themselves better within the collaboration landscape. It also facilitates the identification and development of innovative collaboration concepts. Moreover, transparency in structural complexities, for instance driven by the large number of partners or by the broad geographical scope, helps to direct management attention to the setup of appropriate governance structures and management capabilities. To keep collaboration structures manageable over the lifecycle of the partnership, logistics managers are recommended to pay special attention to the structural aspects outlined. In particular, the high complexity driven by strong functional integrations and complementary resource setups requires logistics managers to strike the right balance between the independence of their individual company and the interdependence within the collaboration.

Based on observed horizontal collaboration projects in practice, Schmoltzi and Wallenburg (2011) use the collaboration landscape to define six archetypes of horizontal collaboration:

1. Dense road-based networks with shared production focus.
2. Customized road transport networks with broad functional integration.
3. Situational road transport networks with shared production.
4. Sea and air freight collaborations with marketing and sales focus.
5. National value-added service collaborations with broad functional integration.
6. Bilateral hinterland collaborations with shared production focus.

These six archetypes (or clusters) are then mapped on the earlier developed collaboration landscape in Figure 26.

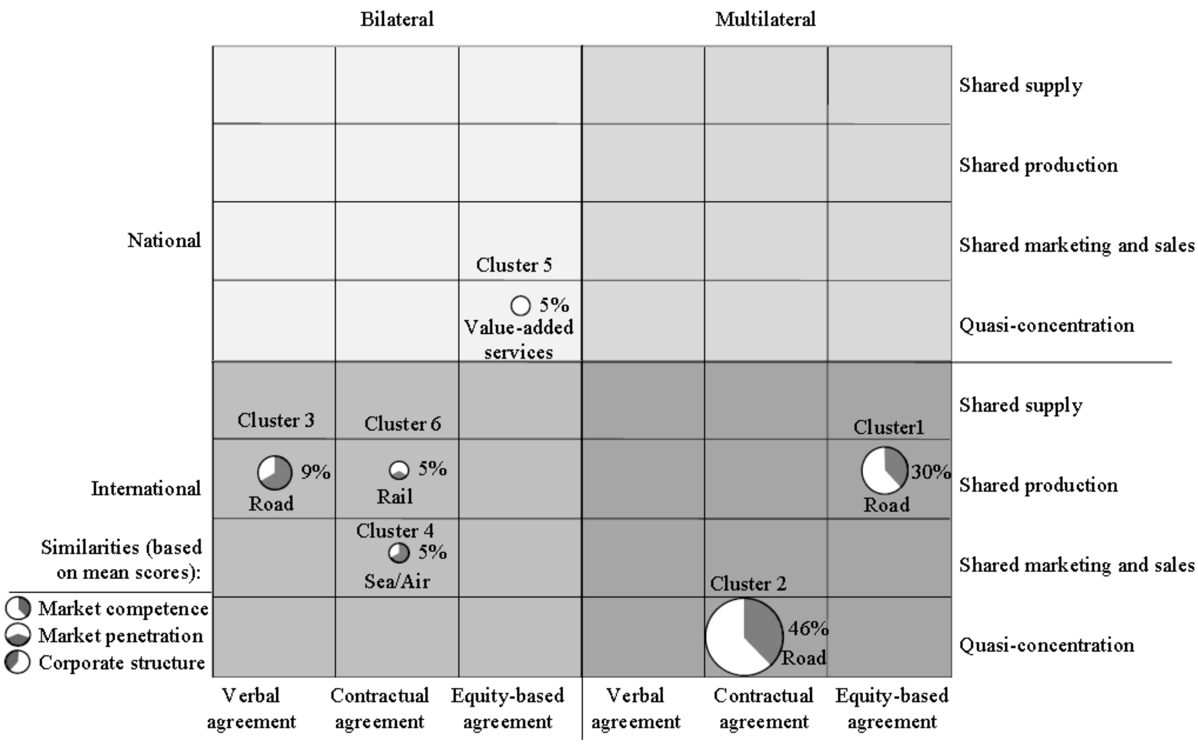

Figure 26. Collaboration archetypes positioned in the collaboration landscape (Schmoltzi and Wallenburg, 2011)

6.1.5 Pomponi et al. (2013)

The fifth typology is proposed by Pomponi et al. in 2013. They segment collaboration initiatives based on 1) their aim and 2) the assets shared. Combined with these two elements, a three-phase growth path is proposed in which initiatives become more ambitious in their aims and more assets are shared, see Figure 27. Each of the three identified stages is characterized by a specific combination of aims and shared assets. Furthermore, they make a remark about the in-company management of various types of collaboration: evolving from operational towards strategic collaborations implies more complex governance architectures and an increasing level of managerial involvement. More specifically, especially in collaboration among SMEs, while the operational and tactical phases may be managed at the Supply Chain Manager level, the strategic ones need direct involvement of the top management.

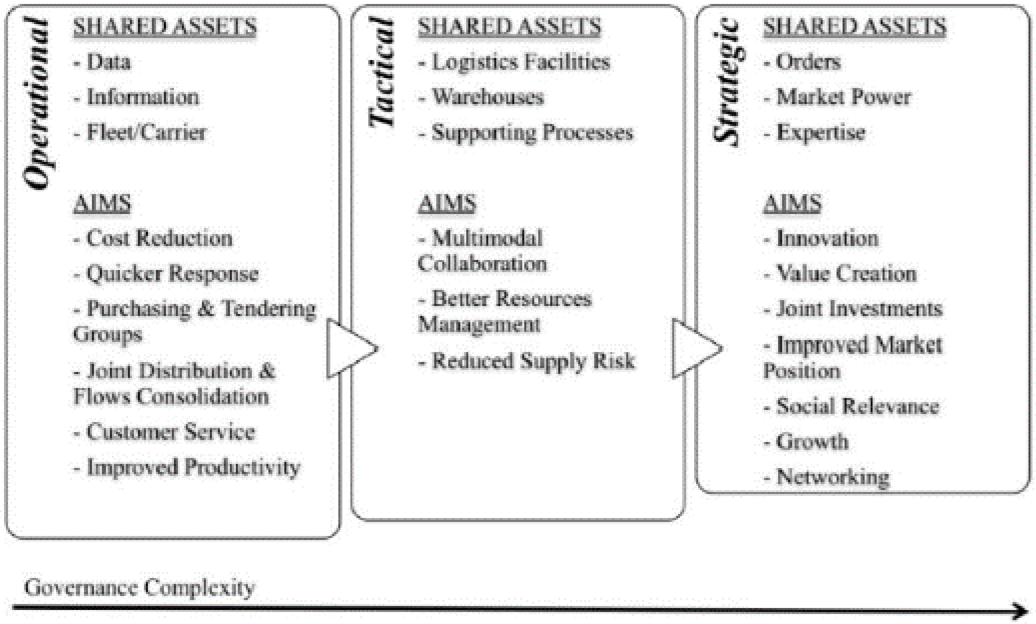

Figure 27. Framework for horizontal collaboration proposed by Pomponi et al. (2013)

6.1.6 Martin et al. (2018)

Martin et al. (2018) identify two key dimensions to categorize horizontal collaborations among LSPs specifically: the activity scope of the alliance and the degree of structural intertwinement among partners. The first dimension, activity scope, refers to the domains in which LSPs join forces. The collaboration can be limited to non-core activities, e.g. purchasing or truck maintenance, or can involve LSP core activities, i.e. transport and warehousing services. A broad activity scope, including both non-core and core activities, is also possible. The structural intertwinement among LSPs, the second dimension in the typology, reflects the degree to which partners' business processes are integrated, their actions are synchronized, and intensive interpersonal relationships are maintained. Moreover, it determines the consequences for an LSP when the alliance's activity scope is reduced, or the collaboration terminates altogether. These two dimensions with respectively two and three levels results in six archetypes for horizontal collaboration, which Martin et al. (2018) define as follows:

- Restrained multidisciplinary alliance
- Noncommittal alliance
- Avoidance alliance
- Integrative alliance
- Profound alliance
- Peripheral alliance

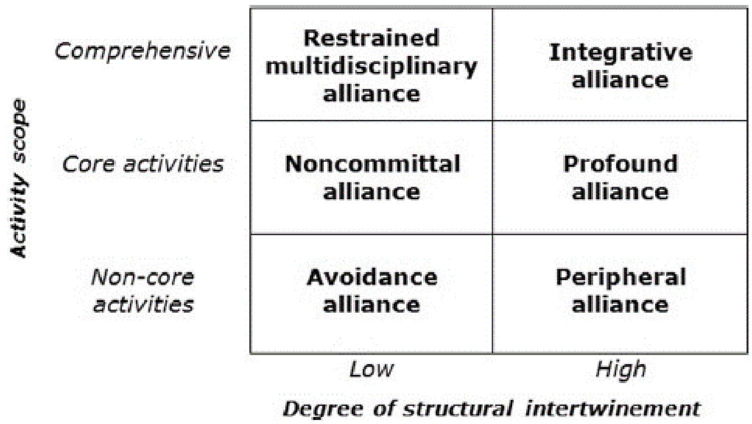

Figure 28. Horizontal collaboration typology developed by Martin et al. (2018)

While a vertical movement in Figure 28 indicates a broadening or narrowing of the collaboration scope, its horizontal counterpart reflects changes in the degree of structural intertwinement. The straightforward structure of the typology allows practitioners to gain insight in the various horizontal collaboration types and position their current or aspired alliance within one of the six categories.

6.1.7 Palmer et al. (2019)

Palmer et al. (2019) take het another approach by listing the archetypical horizontal transport collaborations. They observe the following possible collaboration types:

1. **Co-loading of small deliveries** - the combination of part loads originating from depots located near to each other and destined for the same, or nearby, customer locations.
2. **Consolidation of small deliveries** - the combination of part loads belonging to different companies but originating from the same, multi-user, depot and destined for the same, or nearby, customer locations.
3. **Use of regional consolidation centers** - channeling part-loads through a consolidation center in each region whose location would be optimized with respect to inbound and outbound part load flows and enabling full load movements between regions.
4. **Optimization of urban freight and use of urban consolidation centers** – to receive consolidated part loads from depots or regional consolidation centers some distance from cities and to make freight movement within cities more efficient.
5. **Multi modal opportunities** - being able to achieve critical mass for train movements has been one of the main reasons for not using rail. With the volume from several European companies the use of modes of transport other than road will be examined.
6. **Consideration of logistics clusters** – co-locating of company depots in a cluster to enable consolidation of all flows and enabling full load movements between clusters.

Like Palmer et al. (2019), Pan et al. (2019) conducted a literature review on horizontal collaboration and mapped the papers based on the solution (or collaboration approach) proposed and the main implementation issues discussed.

	Solutions		**Implementation issue**
S1	single carrier collaboration,	**I1**	collaborative network design
S2	carrier alliance and coalition	**I2**	transport planning optimization
S3	transport marketplace	**I3**	mechanism for exchanging requests
S4	flow-controlling entities collaboration	**I4**	gain sharing
S5	logistics pooling	**I5**	communications technology
S6	physical internet	**I6**	Organization
		I7	Management and governance

Table 14. Solutions and implementation issues by Pan et al. (2019)

	Implementation issues							
HCT Solutions	I1	I2	I3	I4	I5	I6	I7	*Total*
S1	0	3	0	0	0	1	0	*4*
S2	2	19	13	3	1	3	2	*43*
S3	0	0	9	0	0	0	0	*9*
S4	1	9	0	19	1	3	5	*38*
S5	2	0	0	0	0	4	0	*6*
S6	0	3	1	0	0	7	0	*11*
General	0	2	0	2	0	1	4	*9*
Total	*5*	*36*	*23*	*24*	*2*	*19*	*11*	*120*

Table 15. Number of papers per solution and per implementation issue in the survey (Pan et al, 2019)

6.2 Selected dimensions

In the previous section we discussed seven typologies for horizontal collaboration in transport and logistics proposed by authors in the last 20 years. As mentioned before together these are useful because they can be used as 1) a design tool for new initiatives, 2) a benchmarking tool, 3) an indicator for changes for success, and 4) an innovation tool to propose initiatives that have not yet been tested in practice.

Although the discussion of collaboration elements in the various typologies is rather detailed already, it can still be argued that some relevant characteristics are still unknown once one typology (or in fact all the typologies) is filled out. Although it is certainly valuable to have a typology that is simple and has as few dimensions as possible, it is not helpful if arguably relevant situational elements are not considered.

Below we discuss six additional collaboration characteristics that in our view should be added to the typology to make it more comprehensive.

6.2.1 Number of partners

The optimal management of a collaboration project of two or three companies is quite different from a consortium of 10 or even many more partners. For example, game theoretical gain sharing based on actual synergies as discussed in Section 5.6 is still possible until a maximum of five or six partners, but more than that makes calculations impractical or even computationally intractable. The more partners, the more difficult it also becomes to reach absolute consensus about the setup and operation of the collaboration. Therefore, it should be managed more centrally and based on predefined rules of engagement. When the number of partners exceeds ten there will likely be a breakpoint for 'classical' horizontal collaboration. From that point onwards, it is best to move from active collaboration to a coordinated market structure with fixed rules, rates, and services, for example like a small-scale physical internet setup, see Section 3.7.

6.2.2 Shipper- or carrier-led

There is a long debate in the Netherland and in the European Union through ALICE if a collaboration is preferable led by shippers or by LSPs. As Leitner et al. (2011) observe, the relevant literature on horizontal collaboration in landside logistics mainly deals with collaboration on the level of LSPs and only few focus on collaboration among shippers. In Dutch collaboration projects, the first wave starting around 2010 was managed by LSPs, then there was a period were shippers took the initiative and recently focus seems to be an LSP collaboration again. Shipper collaboration makes sense because in the end the shipper are the cargo owners and they pay the bill for the transport. Furthermore, transport is not their core activity, so it is easier for shippers to make changes to it without running competitive risks. On the other hand, LSPs are the actors that have most knowledge about the actual process of transport and are therefore better able to judge what is possible and what not. Whatever the preferable setup, it surely is an important element of a collaboration.

6.2.3 Government support

In many European countries government subsidy programs exist for innovative collaborative projects, as they aim at contributing positively to important societal goals such as sustainability, reduced congestion, and overall industrial efficiency. This is very defendable from a policy perspective, but it is also observed that a subsidy changes the dynamics in collaboration project. In some cases, it brings the necessary incentive to make the collaboration work, but in other cases it keeps projects running that would have been stopped much earlies if they were purely business driven.

Governments could also take a more pro-active role in supporting collaboration, if not enforcing it. This can only be done to address a societal challenge which cannot be done by market stakeholders (alone). The societal challenge, e.g. reducing congestion or pollution, is an external influencing factor for horizontal collaboration. In fact first signs of this pro-active role can been seen in city logistics, where municipalities 'close' the city centre for Heavy Duty Vehicles, only allowing zero-emmission vehicles for last-mile distribution. Tax incentives, or tolls, can be considered as an incentive to achieve collaborative logistics. If external effects are 'internalised', costs of freight transport will rise and companies will look for ways becoming more efficient. Horizontal collaboration might be a solution. The effects of these pro-active role, however must be researched in detail and from a holistic point of view.

6.2.4 Partner size

From project experiences in Europe and the Netherlands it can be concluded that a collaboration initiative between large multinationals should be managed much differently than a collaboration between SMEs. In the former, a collaboration initiative among direct competitors will usually be management much more formally (regarding legal contracts etc.) than if the companies are competing SMEs.

6.2.5 Industry specificity

As we will see in Chapter 8, there is a large variety in collaboration initiatives. Notably, some projects are motivated ad-hoc in a certain industry because one or two individuals or companies see a potential to reduce cost or emissions among them. They then start up a collaboration in such a way that it maximizes the probability of success for their company setting. Such a collaboration is perhaps a one-off, but helps the involved companies achieving their goals. On the other hand, there are also collaborations that are initiated by companies that have collaboration support as their business model. Typically, these are more software/technology-based initiatives that are aimed a pool of potential users that is as big as possible, and mostly will not be restricted by a specific industry.

6.2.6 Collaboration experience

Experience with collaboration projects in the last years has shown that it is not easy to make it work, and even more difficult to scale it. Especially in the early phases of development, its success is largely dependent on a small group of *collaboration champions* in the project teams of the consortium partners. Many pitfalls only become clear once they are experienced in a true project. Having these experienced champions with collaboration in the team strongly improves the odds of success.

6.3 An extended horizontal logistics collaboration typology

Together with the dimensions coming from the literature review, these six new elements make up a new extended collaboration typology that is summarized in Table 16 and Table 17.

Dimension	**Based on**
Intensity of the collaboration	Lambert et al. (1999) Leitner et al. (2011)
Decision level	Cruijssen (2006)

	Pomponi et al. (2013)
Competitive or non-competitive	Cruijssen (2006) Schmoltzi and Wallenburg (2011) Martin et al. (2018)
Assets shared	Cruijssen (2006) Schmoltzi and Wallenburg (2011) Pomponi et al. (2013)
Objectives	Cruijssen (2006) Leitner et al. (2011) Pomponi et al. (2013)
Formalization (contractual scope)	Schmoltzi and Wallenburg (2011)
Geographical scope	Schmoltzi and Wallenburg (2011)
Solutions	Palmer et al. (2019) Pan et al. (2019)
Hurdles	Basso et al. (2019) Pan et al. (2019)
Number of partners	*Expert consultation*
Shippers and/or carriers led	*Expert consultation*
Government stimulated	*Expert consultation*
Partner size	*Expert consultation*
Industry specificity	*Expert consultation*
Collaboration experience	*Expert consultation*

Table 16. Dimensions of our extended typology of horizontal collaboration

Intensity of the collaboration	Arm's length	Type I	Type II	Type III	Integration	
Decision level	Operational	Tactical	Strategic			
Competitive or non-competitive	Competitive	Non-compotetive				
Assets shared	Orders	Logistics facilities	Fleet	Market power	Supporting processes	Expertise
Objectives	Cost	Growth	Innovation	Service	CSR	
Formalization (contractual scope)	Unwritten agreement	Contractual agreement	Minority stake agreement	Joint venture agreement		
Geographical scope	Local	Regional	National	Continental	Intercontinental	
Solutions	Co-loading	Consolidation	RCCs	Urban freight	Multimodality	
Hurdles	Design	Planning and operations	Business/market	Behaviors		

<table>
<tr><td>Number of partners</td><td colspan="3">2</td><td colspan="3">[3,5]</td><td colspan="3">[6,10]</td><td colspan="3">More than 10</td></tr>
<tr><td>Shippers and/or carriers led</td><td colspan="4">Shippers</td><td colspan="4">Carriers</td><td colspan="4">Third party</td></tr>
<tr><td>Government stimulated</td><td colspan="6">Yes</td><td colspan="6">No</td></tr>
<tr><td>Partner size</td><td colspan="4">SME</td><td colspan="4">Large</td><td colspan="4">Mix</td></tr>
<tr><td>Industry specificity</td><td colspan="6">Industry-specific</td><td colspan="6">Generic</td></tr>
<tr><td>Collaboration experience</td><td colspan="4">None</td><td colspan="4">limited</td><td colspan="4">Broad</td></tr>
</table>

Table 17. Extended typology for horizontal collaboration initiatives

Our new typology is richer in dimensions than the typologies found in academic literature today. The logical question now is if this is rich enough or will there still be unknown and unexpected complexities even if a collaboration project is described using this complete typology. Unfortunately, the expected answer is that indeed it will be almost impossible to make a complete blueprint of a collaboration based on a fixed number of categorized characteristics. The diversity of industry sectors, logistics processes, geographical aspects etc., is just too big to make this into an exact science. However, we are convinced that carefully describing every aspect in this typology is improves the chances of success for a collaboration project.

6.4 Collaboration development

In the previous section, we have discussed in detail the various aspects that define a collaboration initiative, finally arriving at an extended typology for horizontal logistics collaboration. In addition to this, once a collaboration project is clearly defined based on this typology, it is also important to discuss how the envisioned result can be achieved. A collaboration project is a complex arrangement that cannot simply be ‘switched on’. On the contrary, it requires careful management and a step-by-step growth model. Several tools and publications on this topic are available and we will discuss them below.

6.4.1 Verstrepen et al. (2009)

Verstrepen et al. (2009) to be best of our knowledge were the first to propose a formal stepwise procedure for setting up horizontal collaborations, see Figure 29. In four subsequent phases (strategic positioning, design, implementation, moderation), some key aspects of a collaboration initiative based on Cruijssen (2006) are listed, together with the potential settings of each aspect.

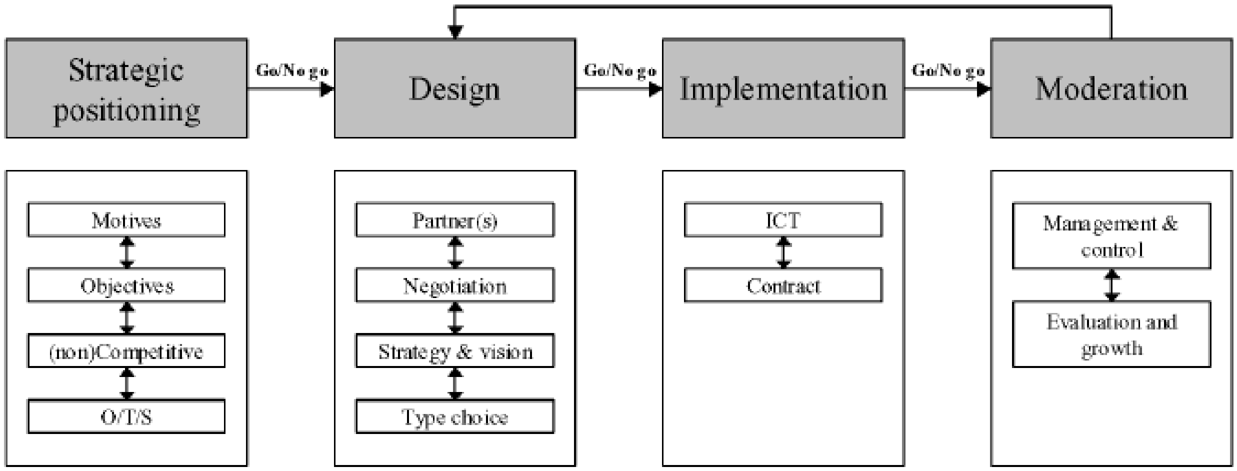

Figure 29. Verstrepen et al. (2009) typology for horizontal collaboration

6.4.2 Nextrust protocol

The Nextrust project is an innovation and coordination action sponsored by the European Union, which will be described in more detail in Section 7.3. One of the main results of this project is the establishment of the so-called Nextrust protocol, see Figure 30, a conceptual collaboration framework to build trusted networks bottom-up.

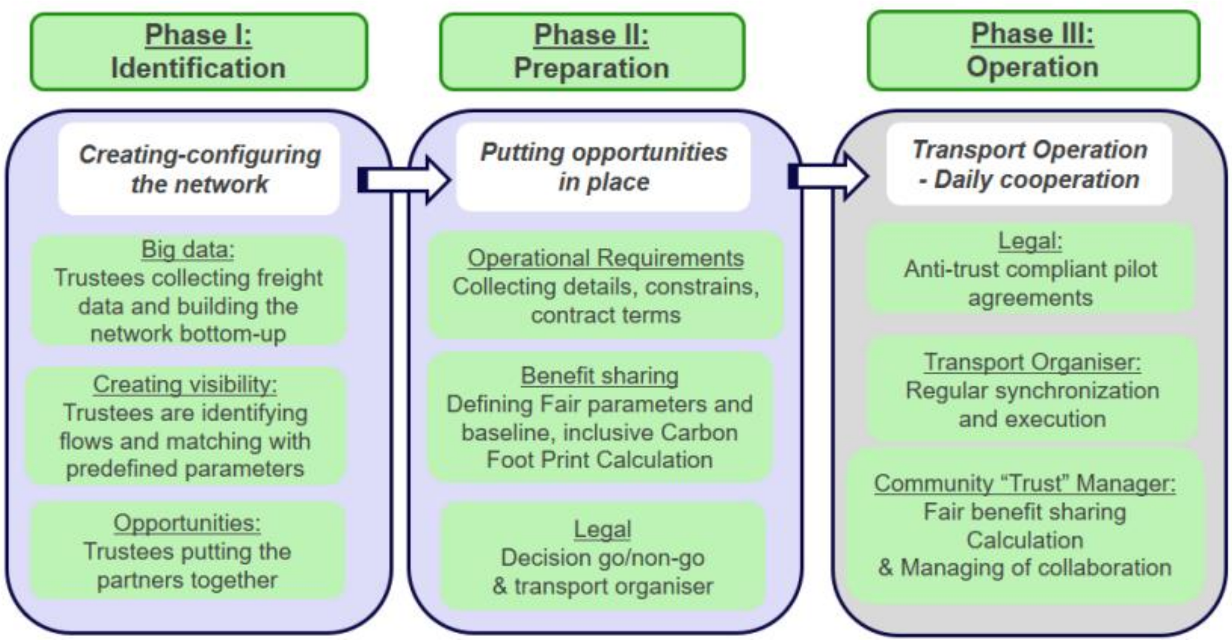

Figure 30. Nextrust collaboration protocol

In their protocol, Nextrust is following a 3-step trusted network research methodology. The first research step is the 'Identification' of opportunities, followed by Preparation, implementing potential matches into pilot scenarios, and then the Operation phase, where the trusted network pilot scenarios are validated in real market environments. Nextrust learned that an identification phase is needed to map the appropriate collaboration components to achieve a breakthrough. They observe that it is challenging that collaboration has historically been regarded a buzzword that invariably has different meanings and attitudes among stakeholders in the supply chain.

6.4.3 Dinalog supply chain collaboration tool

This tool is developed by Dinalog in the Netherlands based on the supervision of many collaboration projects that were co-funded by the Dutch government since 2010, see Chapter 8. The tool proposes a four-step procedure for successfully setting up collaborations. The four main steps (Identification, Design, Implementation, and Evaluation) consist of a few subtopics that are documented with qualitative advices, benchmark projects, references, etc. The tool is summarized in Figure 31.

Figure 31. Dinalog Collaboration tool [Source: https://www.dinalog.nl/samenwerking/]

6.5 QUALITATIVE COLLABORATION INSIGHTS AND ADVICES

To conclude the discussion of horizontal collaboration typologies, in this section we provide some additional insights and qualitative experiences that can be useful to remember when setting up or managing a collaboration project. As such, although maybe not rigorously established in academic literature, these insights contribute to the four goals of a collaboration typology described in Section 6.1.

6.5.1 Gaming

In the western world, generations of students have learned in their industrial economics classes at secondary school how competitive behavior can help companies reach their goals. Concepts such as predatory pricing to push competitors out of the market, profit maximization by monopolists, first mover advantages, etc. are all examples of rather reckless competition that are extensively studied. Much less attention is given to the question how companies can work together to pursue common goals. And once working for a company, often personal and company targets confirm the importance of outperforming your competition. In that sense, horizontal collaboration is a true paradigm shift. Although the current generation of secondary school and university students learn much more about the benefits of collaboration, it is still to be expected that it will take some effort to make collaboration more commonplace in today's competitive markets.

One interesting tool to promote behavioral change and learning is a so-called serious game. Serious gaming is successfully used in various areas such as education, healthcare, marketing and other businesses and industries. The power of serious games is that they are entertaining, engaging, and immersive, while almost unconsciously bringing new possibilities to the minds of the players. Well-designed serious games combine learning strategies, knowledge and game elements to teach specific skills, knowledge, and attitudes. They are designed to solve problems in several areas and involve challenges and rewards, using entertainment and engagement components that appeal to the players.

Recently, several serious games around the topic of horizontal collaboration have been introduced. These are briefly discussed below.

<u>CO3 Trustee game</u>

In the 'Collaboration Trustee Game' (Genta and Cruijssen, 2013) a single player acts as a trustee who wants to create a coalition between shippers taken from a provided set of shippers in France. For these shippers, some relevant shipping data are available. The game is based on an actual collaboration project conducted in France concerning a joint inventory centralization with collaborative deliveries to customers, which are the distribution centers of several retailers.

In this game, the player is challenged to act as a trustee. The set of proposed shippers (all shippers are imaginary) is heterogenic and have different volumes and also a different willingness to cooperate, ranging from hesitant to willing. To create the illusion of a real scenario, the tool offers a short description of each shipper, with logo and KPIs values.

At each turn (equal to one year) all costs, savings and budgets are updated and recorded. A chart reports the evolution of costs during the turn, the collaboration savings and the final budget at the end of each year. There is also a scoreboard table where best players are reported together with their final budgets, see Figure 32.

Each turn the player can:

- Change the coalition: the player can change the coalition by adding or removing shippers. Each change has a cost that depends on the number of shippers that enter or leave the coalition, due to management and legal work needed to change the coalition.
- Ask for an advice: the player can pay a sum of money to ask an external advice to identify the best change he can make (or the best two shippers coalition to start with).
- Improve the gain sharing rule: while not directly affecting savings, the gain sharing rule used affect the stability of the coalition. To improve the stability the player can invest in changing the sharing rule to a more stable rule.
- Do nothing: a possible action is also to do nothing, letting the coalition unchanged. In this case costs and savings are applied and the budget changes consequently.

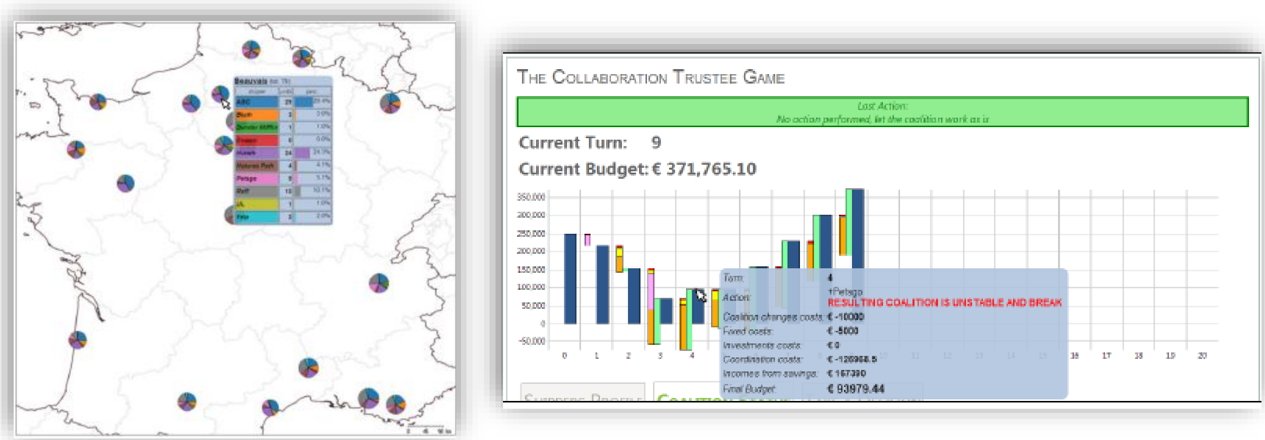

Figure 32. CO3 trustee game.

<u>TRUST cards game</u>

Trust is mentioned by many academics and practitioners as an essential condition for successful horizontal collaboration, see also Section 5.3. But in practice it is often treated as a static phenomenon: it is there, or not. Little attention is given to the question how trust can be deepened. In 2017, the Dutch organization TKI Dinalog has developed a cards game (See Figure 33) to let players experience how trust can add to the success of collaborative logistics projects. In the game, various aspects of trust are explored, and players are challenged to apply the lessons learned to their own organization. Each card has a statement about collaboration, which is discussed among the players. The group then decides if they agree or disagree with the statement and, they rank the card (and statements) in order of relevance for a successful management of a collaboration.

Figure 33. Trust cards game

The Fresh Connection

The Fresh Connection is a web-based business simulation game. It challenges participants to make the best strategic decisions in the management of a manufacturing company of fruit juices. Working in teams of four, participants will represent the company's management team and will be confronted with various real-life dilemmas. Cross-functional understanding and collaboration are key components, as teams work together to make the company successful.

The Fresh Connection immerses its participants in turning around a manufacturer of fruit juices. Faced with declining performance, the management team must get the company back on track as soon as possible. It is a high-pressure environment in which effective SCM is the key to success. The management team has four roles:

- VP Purchasing: Responsible for selecting the right suppliers and agreeing SLAs with suppliers, including possible collaboration options.
- VP operations: Must decide on capacity in warehouses and production areas and approve investment in bottling lines and mixers. Can introduces various improvement projects. Has the ability to outsource outbound warehousing.
- VP Supply Chain: Manages inventories (safety stock and lot size settings), production intervals and the frozen period of production.
- VP Sales: Agrees SLAs with customers, manages the product and customer portfolio, forecasts demand and can introduce collaboration concepts.

Every decision a participant makes has trade-offs, both within and across roles, so participants will only succeed if they align all the disciplines. As the simulation evolves it becomes clear that a smart and collaborative supply chain strategy is essential for success.

Figure 34. The Fresh Connection game [Source: thefreshconnection.biz]

<u>Freight Transport Game</u>

In 2018, a consortium of French research institutes headed by Armines/ParisTech developed a freight transport game with the objective to let players experience:

1. The difficulty for transport companies to increase their efficiency.
2. The potential mechanisms for a reliable and efficient transport market.
3. Behaviors of the actors in some situations of competition versus collaboration.
4. The dynamics of the transport industry efficiency.

The game challenges players to compare a simplified traditional transport industry (no transit nodes and no re-allocation) with a Physical Internet inspired industry organization with multiple transit nodes, collaboration between carrier companies and possible re-allocation of loads among carriers, see Figure 35.

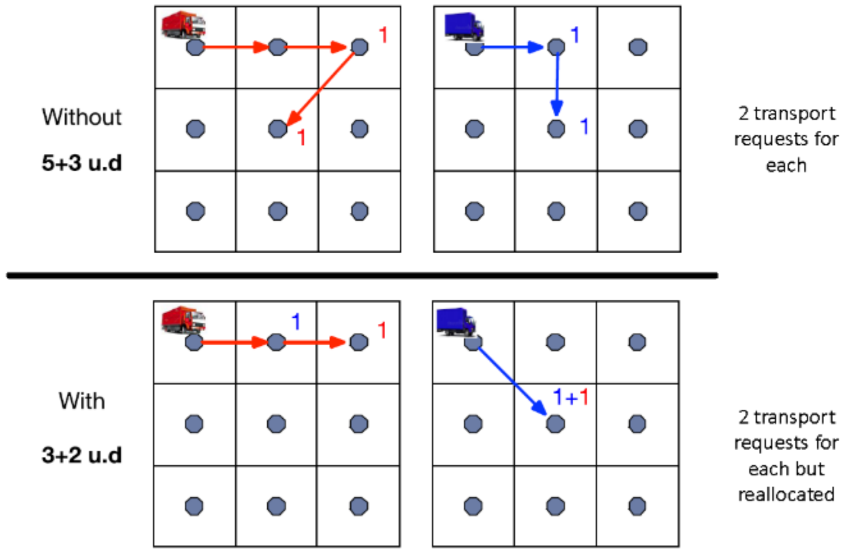

Figure 35. Armines/ParisTech Freight Transport Game

On a stylized map of Europe (See Figure 36), players must carry out transport requests in an auctioning setting. Every round, each player chooses the route he/she wants to travel, the request bundles he/she wants to carry out, and the price he/she is willing to pay or receive for transport requests he/she sells or buys. In the collaboration scenario, in the central node transport request exchange is possible between carriers, while in the traditional situation carriers must always execute the transport requests from their own customers.

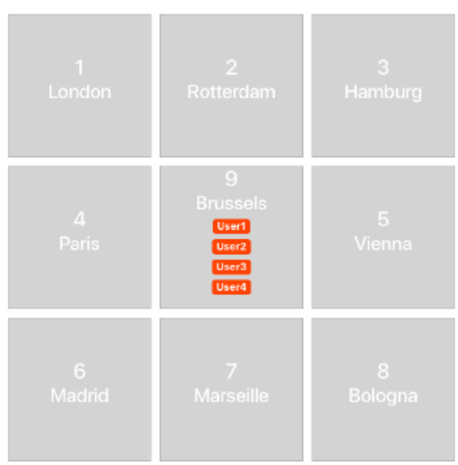

Figure 36. The game board of Armines/ParisTech Freight Transportation Game

6.5.2 Qualitative critical success factors

The serious games described in the previous subsection are useful tools to clarify and sometimes modify behavior of logistics decision makers in collaborative settings. In this section we continue with this topic by providing some qualitative advice for these decision makers based on experience and lessons learned from practical projects.

One of the earliest extensive reports on shipper collaboration was produced by TNO (2005). Based on early experiences with horizontal collaboration among shippers they identified ten success factors subdivided in three categories, see Table 18.

Purpose	
1	Look beyond logistics cost savings, often improved service is the true key to success.
2	Horizontal collaboration is easier with companies that deliver to the success customers but are not directly competing.
3	Be selective in which part of the product flow is bundled. For example, start with only the small LTL shipments.
4	Make sure of a fair gain sharing model.
Organization and management	
5	Start the collaboration with a small group of shippers.
6	At the beginning of the collaboration, clearly describe the conditions for entry and exit.
7	Carefully discuss how (ICT systems of) the consortium members share information.
Process and culture	
8	Think in each other's best interest and commit to the collaboration.
9	Make sure that both the people and organizations collaborating have a good fit.
10	Success takes time.

Table 18. Critical success factor for horizontal collaboration among shippers (TNO, 2005).

BCI (2017) documented the qualitative lessons learned from ten years of collaboration projects in the Netherlands. Through a series of workshops with collaboration experts from industry and academia, a list of lessons was created, an anthology of which is listed below:

1. *Collaboration is all about leadership and responsibility, the willingness to act.*
2. *Do not give up. Collaboration pays of in the long run.*
3. *Do not communicate benefits in monetary values, but in common goals such as reduced emissions.*
4. *Listen to each other.*
5. *Formulate short-term goals to also reap long hanging fruit.*
6. *Use simple, commonly understandable language.*
7. *Stress the importance of logistics to senior management, it is more than a cost factor.*
8. *Try to understand each other's motivations to collaborate.*
9. *Horizontal collaboration is not limited to working with your competitor, the company next door might also be a good partner.*
10. *Guarantee openness and fairness and avoid arbitrariness.*

11. *Transparency is needed, but only for the necessary information. You do not have to share everything.*
12. *Organize regular workshops and inspiration meetings to create trust and a sense of commonality.*
13. *Organize good consortium meetings with a clear agenda and mandate.*
14. *Be flexible and tolerant toward your partners.*
15. *Celebrate successes, both in the consortium and externally with press releases.*

Another set of advices is listed by Professor Ard-Pieter de Man. Based on this experience, in 2015 he formulated the following *ten commandments* for horizontal collaboration:

1. *Have measurable goals*
2. *Start simple, with a stepwise approach*
3. *Ensure enough capacity*
4. *Work on behavior, trust, and commitment*
5. *Keep your eyes on the long term*
6. *Ensure good communication*
7. *Construct a good governance structure*
8. *Agree on the financial model beforehand*
9. *Be flexible to change agreements when necessary*
10. *Determine clear conditions for entry and exit*

A final qualitative tool we present is the collaboration matrix, see

Figure 37 and Table 19, which can be used by companies to judge if another company could be a possible partner to collaboration with. The matrix categorizes companies into four groups depending on two main aspects: their willingness to collaborate and their 'collaboration value', which is the additional synergy that a company adds to a consortium.

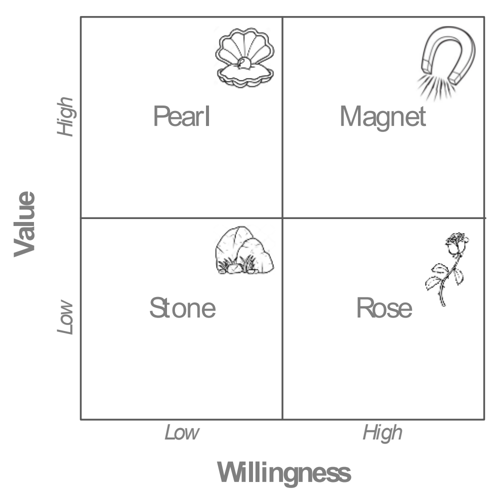

Figure 37. Horizontal collaboration matrix

	Explanation
Pearl	This company has a supply chain that can provide interesting savings should it enter horizontal collaboration. However, the willingness (or is some cases awareness) is not there yet. Successful project examples might help to give horizontal collaboration a chance.
Magnet	There is both a strong willingness to collaborate and the logistics profile of the company allows many bundling opportunities with other companies. This is the ideal collaboration partner and can even perform a motivating role for other companies to engage in collaboration.
Stone	No willingness and no synergetic value. This company can be left out of consideration for collaboration.
Rose	A company with a strong willingness to collaborative, however there is no synergetic fit with it as a bundling partner. This can possibly be changed by relaxing some transport restrictions, service levels or time constrains. If that is successful, a Rose can change into a Magnet.

Table 19 Legend of the horizontal collaboration matrix.

As a final remark in this chapter, we can conclude that collaborative logistics has become a hot topic in all kinds of media, ranging from rigorous academic journals to mainstream- and social media. Typically, the larger share of the publications is written by 'believers', i.e. people who in principle have a positive attitude towards horizontal collaboration. With their contributions they wish to stimulate collaborative behavior in SCM, although sometimes by pinpointing their challenges and disappointments. It is good to keep this in mind while going through the growing body of formal and informal literature on collaborative logistics.

7 APPLICATIONS OF CROSS-CHAIN COLLABORATION

Having introduced a broad typology of horizontal collaboration projects and practical guidelines for its management in the previous chapter, again it is time to take a step from theory to practice and study some empirical evidence. Generally, empirical papers on horizontal collaboration either focus on survey results on the (perceived) opportunities of impediments, or they discuss one or a few true cases in detail. We start with the survey papers and then continue with descriptions of collaborative projects found in academic literature. Then, we focus our attention to relevant European Union policies and projects, and we conclude this chapter with an overview of some recent commercial initiatives that foster collaboration in logistics.

7.1 SURVEYS

The benefits and difficulties of horizontal collaboration have been studied in several empirical papers based of surveys. Cruijssen et al. (2007c) surveyed 155 LSPs in Flanders and based on the responses ranked the importance of proposed opportunities and impediments of horizontal collaboration.

	Opportunities	Score (1-5)
O1	Horizontal collaboration increases the company's productivity for core activities, e.g. decrease in empty hauling, better usage of storage facilities etc.	4.17
O2	Horizontal collaboration reduces the costs of non-core activities, e.g. organizing safety trainings, joint fuel facilities, etc.	3.65
O3	Partnerships reduce purchasing costs, e.g. vehicles, onboard computers, fuel etc.	3.42
O4	LSPs can specialize while at the same time broadening their services.	3.74
O5	Tendering on larger contracts with large shippers becomes possible.	3.60
O6	LSPs can offer better quality of service at lower costs, e.g. in terms of speed, frequency of deliveries, geographical coverage, reliability of delivery times etc.	3.56
O7	Forming partnerships helps to protect market share.	3.24
	Impediments	
I1	It is hard to find commensurable LSPs with whom it is possible to cooperate for (non-)core activities.	3.84
I2	It is hard to find a reliable party that can coordinate the collaboration in such a way that all participants are satisfied.	4.00
I3	When an LSP cooperates with commensurable companies, it becomes harder to distinguish itself.	3.52
I4	It is hard to determine the benefits or operational savings due to horizontal collaboration beforehand.	3.54
I5	It is hard to ensure a fair allocation of the shared workload in advance.	3.73
I6	A fair allocation of the benefits is essential for a successful collaboration.	4.11
I7	Smaller companies in the partnership may lose clients or get pushed out of the market completely.	3.95
I8	Collaboration is greatly hampered by the required indispensable ICT-investments.	3.43
I9	Benefits cannot be shared in a fair way; the larger players will always benefit most.	3.60

Table 20. Opportunities and impediments surveyed by Cruijssen et al. (2007c)

According to Table 20 the most severe impediments for collaboration are the problems of finding a reliable party that can coordinate the collaboration in such a way that all participants are satisfied (I2) and the construction of fair allocation mechanisms for the attained savings (I5).

A comparable study was conducted by Eye for transport (2010). The results are presented in Figure 38 and Figure 39.

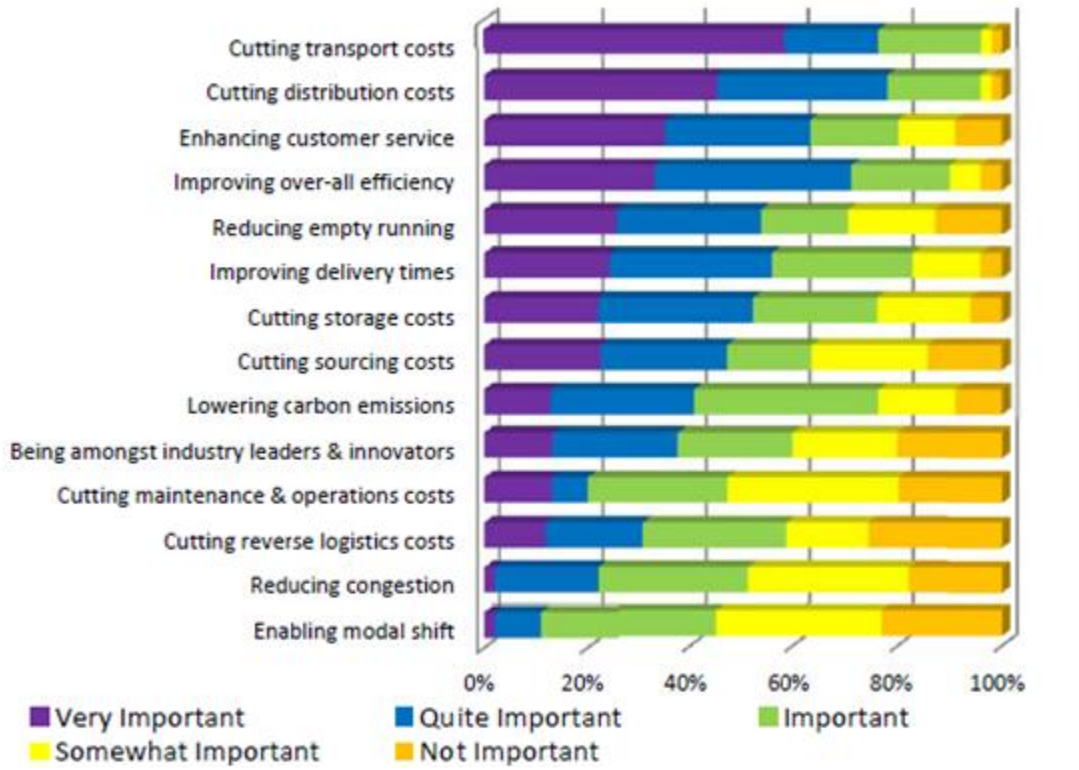

Figure 38. Opportunities for horizontal collaboration (Eye for transport, 2010)

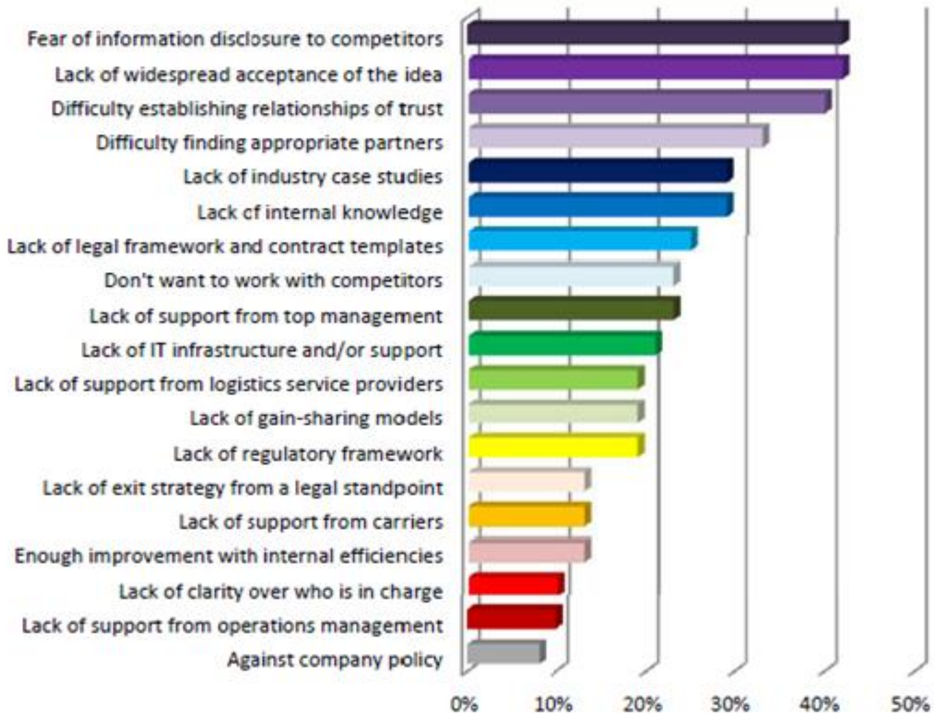

Figure 39 Impediments for horizontal collaboration (Eye for transport, 2010)

The findings regarding the opportunities are well in line with Cruijssen et al. (2007c). The most important opportunity is a reduction of operational cost, here split into two categories, transport and distribution. Maybe the most striking observation is that respondents do not consider modal shift as an important opportunity for horizontal collaboration. For the impediments, the study paints a somewhat different image. The most important impediment is the fear of sharing information with competitors. Following that, there is a group of impediments that have to do with finding trustworthy partners to collaborate with. They can be covered by getting a comprehensive legal and contractual framework in place and by having a clear approach for partner selection (See Section 5.7.1).

In another study, Pateman et al. (2016) surveyed 32 senior logistics managers about the enablers for logistics collaboration in Australia. Being questioned on the top factors for successful collaboration, the respondents were to choose three critical factors, which they ranked. The weighted index that was derived from the responses can be found in Table 21. The authors conclude that collaboration is a natural consequence of the competitive dynamics of logistics activities in Australia. The number of collaborations in Australia is expected to grow over the next 10 years.

Category	Theme	Weighted value
Mutual benefits	Business growth	9
	Enabling solutions	5
	Way of doing business	0
	Mutual benefits	11
	Other	9

Spirit of collaboration	Relationship building	36
	Interpersonal skills	46
	Business facilitation	58
	Other	8

Table 21. Enablers for collaboration by Pateman et al. (2016)

Saenz et al. (2017) provide some empirical evidence about horizontal collaboration based on several case studies. They state that horizontal collaboration is difficult to accomplish but hugely rewarding for those companies that do it successfully. They observe several drivers of horizontal collaboration, ranging from the demands of globalization to a marketing advantage (Figure 40). Despite these potential gains, horizontal collaboration adoption is not widely practiced, for several reasons listed in Figure 41. These include human fallibilities, primarily a lack of trust and a fear of failure and the effort required to implement new ideas, as well as operational difficulties.

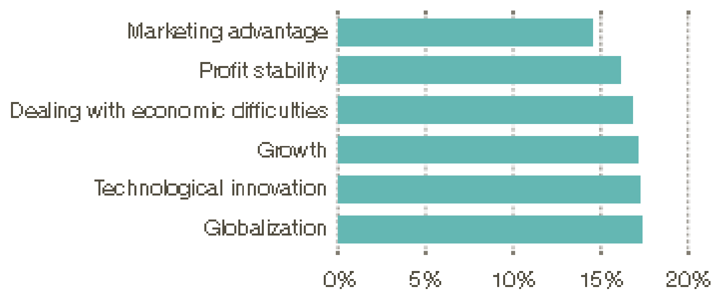

Figure 40. Advantages of horizontal collaboration (Saenz et al., 2017)

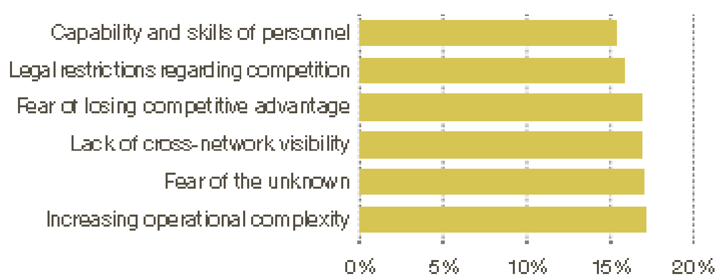

Figure 41. Barriers to horizontal collaboration (Saenz et al., 2017)

Karam et al. (2019) also observe that although horizontal collaboration has gained an increasing attention in literature as an efficient practice for sustainable freight transport, successful applications are rarely reported. Therefore, they conducted an empirical study to find the main barriers to the implementation of collaborative freight transport in practice. A set of barriers was identified by an extensive literature review, and is grouped into six categories, i.e. 'Design of the collaboration process', 'Information sharing and collection', ' Partners' behaviors and their relationships', 'Decision making algorithm', 'Web-based information system', and 'Market structure and regulating laws'. Then, a DEMATEL method is used to develop causality and prominence relations among these categories, starting with the question: "Why do implementations of collaborative transport fail?". The results are summarized in Figure 42. They show that 'Market structure and regulating laws' and 'Partners' behaviors and their relations' are the most critical barriers to the success of collaboration process. 'Web-based information system' has the lowest contribution to the success of the collaboration process. Therefore, guidelines for decision makers should put emphasis on the factors related to 'Market structure and regulating laws' and 'Partners' behaviors and their relations'.

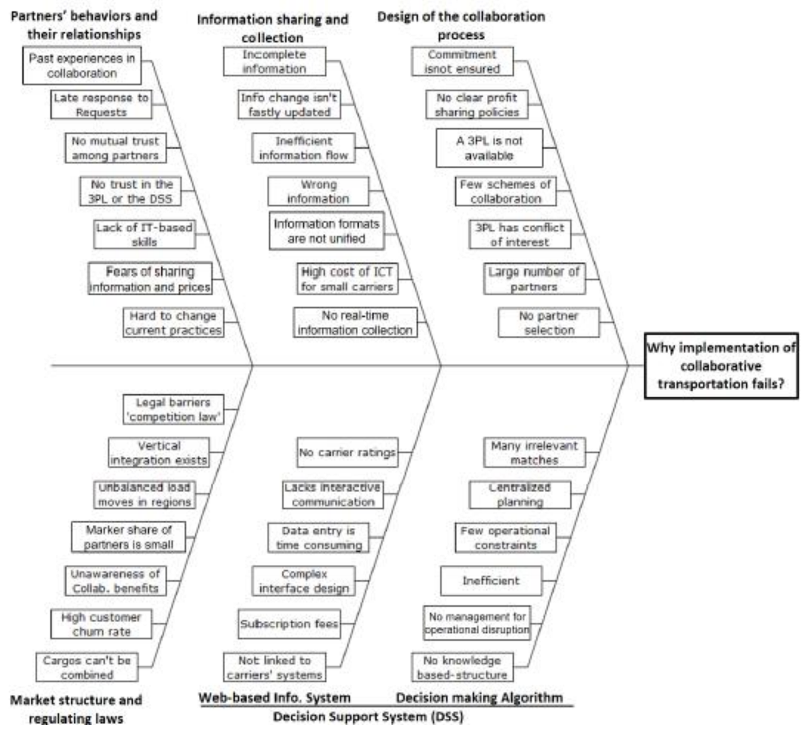

Figure 42. Fishbone diagram indicating the barrier categories and their related barriers (Karam et al., 2019)

Nextrust (2018) conducted a survey in Germany about horizontal collaboration. A total of 121 representatives from the FMCG industry participated, most of which are representatives from large companies. Small and medium-sized companies represent 26 percent of participants. 5 percent of the study participants are employed in micro companies. The full results are shown in Figure 43 - Figure 45, and the following are the main insights collected:

- Companies from the FMCG sector express great interest in becoming involved in logistics collaboration in the future.
- Standards are a prerequisite for the successful implementation of collaborative networks.
- The motivation of the companies to collaborate is based on economic as well as ecological parameters.
- The saving potential that can be realized through efficiency gains from collaboration in logistics is underestimated by the market.

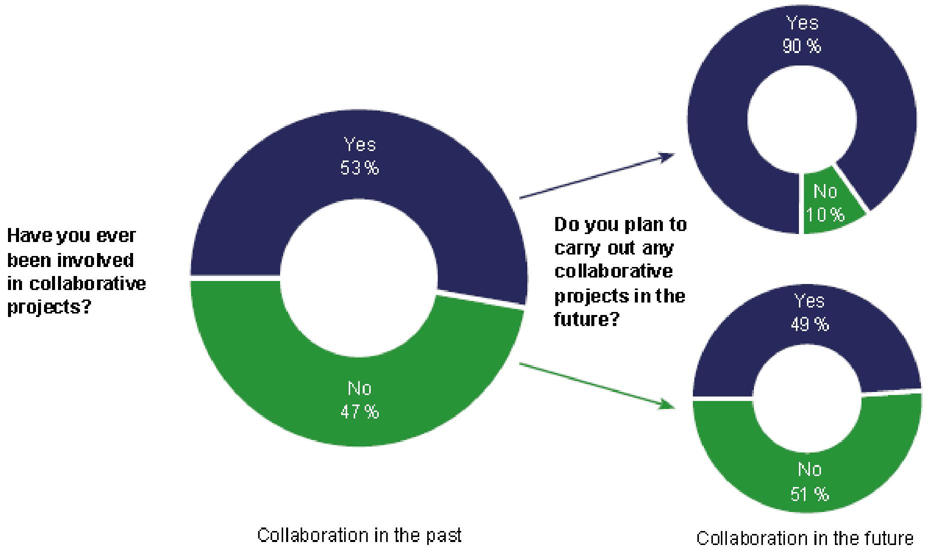

Figure 43. Willingness to collaborate now and in the future (Nextrust, 2018)

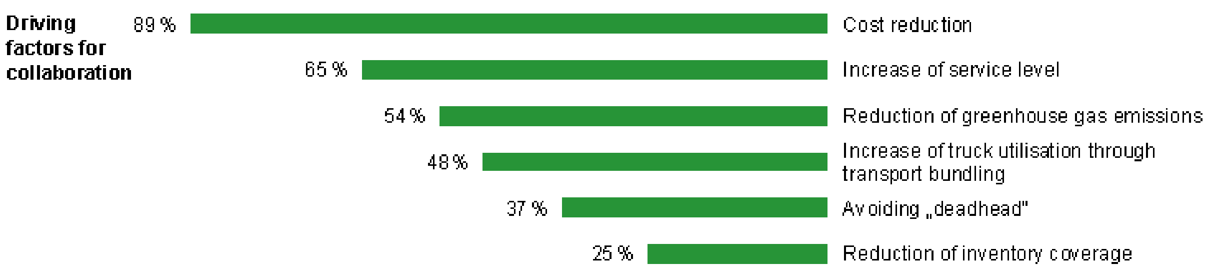

Figure 44. Opportunities for collaboration (Nextrust, 2018)

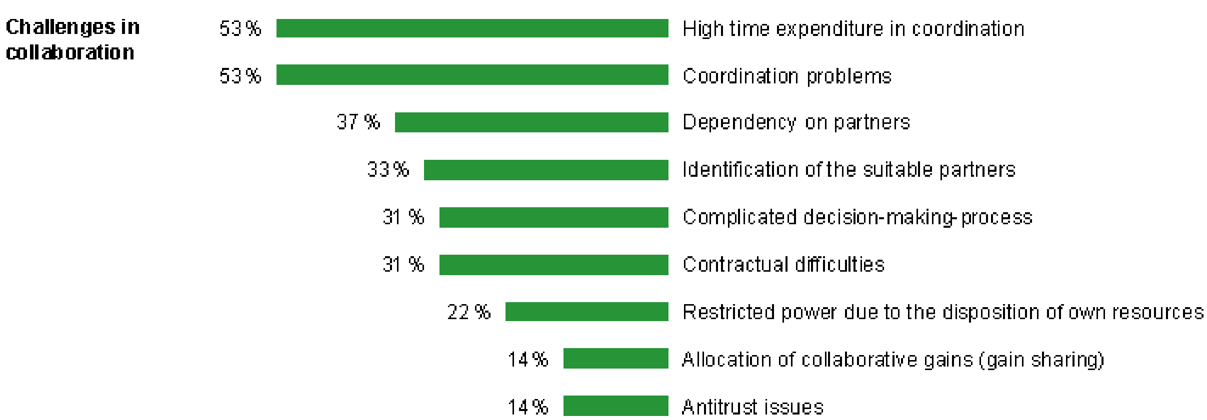

Figure 45. Impediments for collaboration (Nextrust, 2018)

Next to the empirical studies we mentioned above, there are also some academic contributions that provide a list of opportunities and/or impediments for horizontal collaborations based on analysis and industry feedback, but without testing it on a wide scale with a questionnaire. Instead, they often use a case study approach, which is the topic of the next subsection.

7.2 CASE STUDIES

The empirical literature on case studies is larger than the literature on surveys. One of the benefits of case studies is that they explain in detail how in a certain industry setting a collaboration was set up, what the difficulties were, where the benefits were found and how these benefits could be quantified. Unfortunately though, in most papers collaboration is tested in a laboratory environment instead of in a real business setting.

According to Gansterer and Hartl (2018) the cost advantages of collaborations have been quantified in several studies. They observe that most of them find (potential) benefits of 20-30%. Also, ecological goals like reduction of emissions, have been considered. However, most of these studies assume deterministic scenarios. Literature assessing collaboration potentials in the face of uncertainties is scarce. Also, collaboration gains in more complex, e.g. multi-modal, multi-depot transport systems have yet to be widely investigated.

In their review paper on cost allocation methods for collaborative transport, Guajardo and Rönnqvist (2016) provide an overview of numerical results found in 55 academic papers. These numerical computations range from small illustrative examples to thorough case studies. For the publications using industrial data, they also listed the potential savings from collaboration, if reported. It shows that collaboration usually renders significant benefits, ranging from 4% to 46% cost savings, see Table 22.

Reference	**Reported savings**
Engevall et al. (2004)	46%
Krajewska et al. (2008)	11.5%
Cruijssen et al. (2010)	23.7%
Frisk et al. (2010)	8.6%, 9.3%, 14.2%
Massol and Tchung-Ming (2010)	10.5%, 11.9%, 12.9%
Audy et al. (2011)	12.9%
Dahl and Derigs (2011)	13.85%
Lehoux et al. (2011)	4%
Flisberg et al. (2015)	5.99%; 22.18%
Vanovermeire et al. (2014)	25.83%, 41.81%
Guajardo and Rönnqvist (2015)	8.6%, 9.3%, 14.2%

Table 22. Reported savings in industrial cases based on Guajardo and Rönnqvist (2016)

7.3 EUROPEAN POLICY

Logistics project calls by the European Union through its funding schemes[19] are formulated by close consultation of industry stakeholders and experts through the so-called European Technology Platform, ALICE (Alliance for Logistics Innovation through collaboration in Europe).

ALICE was launched on June 11, 2013 and received official recognition from the EC in July 2013. ALICE has been set up to develop a comprehensive strategy for research, innovation and market deployment of logistics and SCM innovation in Europe with the mission 'to contribute to a 30% improvement of end to end logistics efficiency by 2030'.

One of the key elements identified by ALICE to achieve this improvement is the Physical Internet (PI) concept. PI is pursuing an open global logistic system founded on physical, digital, and operational interconnectivity, aiming to move, store, realize, supply and use physical objects throughout the world in a manner that is economically, environmentally and socially efficient and sustainable (See Section 3.7). On its journey to achieve the PI, ALICE has identified five different areas that need to be specifically analyzed and addressed in future research projects. These areas are:

1. Sustainable and Secure Supply Chains.
2. Corridors, Hubs and Synchromodality.
3. Information Systems for Interconnected Logistics.
4. Global Supply Network Coordination and Collaboration.
5. Urban Logistics.

Five different Thematic Groups have been launched, one in each of these areas, to further analyze and define research and innovation strategies, roadmaps and priorities agreed by all stakeholders. For the purpose of this report on cross-chain consolidation centers, the research roadmap in the field of Global Supply Network Coordination and Collaboration is most relevant. ALICE notes that coordination and collaboration can enable synergistic use of resources in global supply networks, with significant gains in terms of both efficiency and sustainability. This will be a big step towards the PI, ultimately leading to open global supply networks that are operated as a whole, meaning with full vertical coordination and horizontal collaboration along and across currently individually managed supply chains.

ALICE provides a network for interdisciplinary collaborative research involving industry, academia, and public institutions. And using this network it defines its research and innovation strategies, roadmaps, and priorities to achieve its vision. These items will then assist the European Commission in the definition of Research and Innovation Programs, the most recent framework program being HORIZON Europe.

Out of industry consultation through ALICE came several innovation and coordination project calls that have been awarded to European consortia of companies, research institutes, and sometimes governments. The projects that are most intricately connected to horizontal collaboration are briefly discussed[20] in the following subsections.

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[19] FP7, Horizon2020, Horizon Europe (https://ec.europa.eu/info/horizon-europe-next-research-and-innovation-framework-programme_en)

[20] Based on https://ec.europa.eu/inea/en/horizon-2020/h2020-transport/projects-by-field/399

7.3.1 CO3

The EU-funded project 'Collaboration Concepts for Co-modality', or 'CO3' in short, is a project that aimed to develop, professionalize, and disseminate information on the business strategy of logistics collaboration in Europe. The consortium ambitioned to deliver a concrete contribution to increasing load factors, reducing empty movements and stimulating co-modality, through collaboration between industry partners, thereby reducing transport externalities such as greenhouse gas emissions and costs. The project coordinated studies and expert group exchanges and built on existing methodologies to develop legal and operational frameworks for collaboration through freight flow bundling in Europe. Furthermore, the project consortium of knowledge institutes and industry partners developed joint business models for logistics collaboration. The developed tools, technologies and business models are applied and validated in the market via case studies. Finally, the CO3 consortium promoted and facilitated matchmaking and knowledge-sharing through conferences and practical workshops to transfer knowledge and increase the market acceptance of collaboration.

Project period: April 2011 – April 2014. **EU Funding received**: 2 million euro.

7.3.2 Nextrust

The objective of NEXTRUST was to increase efficiency and sustainability in logistics by developing interconnected trusted collaborative networks along the entire supply chain. These trusted networks, built horizontally and vertically, should fully integrate shippers, LSPs and intermodal operators as equal partners. To reach a high level of sustainability, focus is not only on bundling freight volumes, but also on shifting them off the road to intermodal rail and waterway. NEXTRUST focused on research activities that create stickiness for collaboration in the market, validated through pilot cases in live conditions. The action engages major shippers as partners (Beiersdorf, Borealis, Colruyt, Delhaize, KC, Mondelez, Panasonic, Philips, Unilever) owning freight volumes well over 1.000.000 annual truck movements across Europe, plus SME shippers and LSPs with a good innovation track record. The pilot cases cover the entire scope of the call and cover a broad cross section of the entire supply chain (from raw material to end-consumers) for multiple industries. Nextrust expects its pilot cases to reduce deliveries by 20%-40% and to reduce GHG emissions by 40%-70% with modal shift.

Project period: May 2015 – October 2018. **EU Funding received**: 18 million euro.

7.3.3 SELIS

Project SELIS (acronym for Shared European Logistics Intelligent Information Space) is aimed at delivering a 'platform for pan-European logistics applications' by:

- Embracing a wide spectrum of logistics perspectives and creating a unifying operational and strategic business innovation agenda for pan European Green Logistics.
- Establishing a strong consortium of logistics stakeholders and ICT providers, that can leverage EU IP from over 40 projects so as to create proof of concept Common Communication and navigation platforms for pan-European logistics applications deployed in eight living labs representing the principal logistics communities.

- Establishing a research and innovation environment using the living labs to provide data than can be used for discovery of new insights that will enable continuous value creation supporting the large-scale adoption of SELIS.

SELIS is a network of logistic communities' specific shared intelligent information spaces termed SELIS Community Nodes. SELIS Community Nodes are constructed by individual logistics communities to facilitate the next generation of collaborative, responsive and agile green transport chains. SELIS Community Nodes link with their participants' existing systems through a secure infrastructure and provide shared information and tools for data acquisition and use, according to a cooperation agreement. Connected nodes provide a distributed common communication and navigation platform for European-wide logistics applications. Each Node decides what information it wishes to publish and what information it wants to subscribe to. The principle of a SELIS Community Node is that it provides a 'lightweight ICT structure' to enable information sharing for collaborative sustainable logistics for all logistics companies, from strategic to operational levels.

Project period: September 2016 – August 2019. **EU Funding received**: 17.7 million euro.

7.3.4 AEOLIX

Supply chain visibility supported by easy access to, and exchange and use of relevant logistics information is an important prerequisite for the deployment of pan-European logistics solutions that are needed to increase efficiency and productivity, and to reduce environmental impact. Although there is a strong development of logistics-related data stores, information channels, information management systems and data mining facilities, with both international and intermodal focus, this multitude of solutions exhibits a high degree of fragmentation, due to differences in user requirements, data models, system specification and business models. This legacy situation severely hampers the use of logistics information.

To overcome this fragmentation and lack of connectivity of ICT-based information systems for logistics decision making, AEOLIX established a cloud-based collaborative logistics ecosystem for configuring and managing (logistics-related) information pipelines. This digital business ecosystem creates visibility across the supply chain, enabling more sustainable and efficient transport of goods across Europe. An essential element of the approach is to ensure that for logistics actors connecting to and using the ecosystem has a low complexity barrier. The developed ecosystem enables the integration of transport processes through logistics software solutions for cloud-based connectivity and interaction, to support more efficient collaboration in the logistics supply chain than today.

Project period: September 2016 – August 2019. **EU Funding received**: 16.2 million euro.

7.3.5 Clusters 2.0

Clusters 2.0 is a Horizon 2020 project leveraging the potential of European Logistics Clusters for a sustainable, efficient, and fully integrated transport system. It relies on an open network of logistics clusters operating in the frame of the Ten-T corridors and supporting local, regional, and European development, while keeping neutral the impacts such as congestion, noise, land use and pollution levels.

It enhances coordination among logistics stakeholders within and among European logistics clusters. The project conducted the following activities to meet its objectives:

- Increase the engagement, performance and coordination of terminals and hubs in the clusters.
- Achieve a significant step forward in the European transport performance through a hyper connected network of logistics hubs and clusters.
- Develop low-cost and low-capital material handling and transshipment solutions.

Project period: May 2017 – April 2020. **EU Funding received**: 6 million euro.

7.3.6 LOGISTAR

The EU faces the challenge to maintain and increase its economic growth and cope with the problem of freight transport efficiency in Europe. Integration of transport volumes and modes, better use of capacity, flexibility, resource efficiency and collaboration between all actors along the logistic chain are required.

Aligned with the European policies and the ALICE roadmap, LOGISTAR's objective is to allow effective planning and optimization of transport operations in the supply chain by taking advantage of horizontal collaboration, relying on the increasingly real-time data gathered from the interconnected digital environment. For this, a real-time decision making tool and a real-time visualization tool of freight transport will be developed, with the purpose of delivering information and services to the various agents involved in the logistic supply chain, i.e. freight transport operators, their clients, industries and other stakeholders such as warehouse or infrastructure managers.

LOGISTAR will address several advances beyond the state of the art in the interdisciplinary field of smart algorithms for data processing: Artificial Intelligence focused on prediction, parallel hybrid metaheuristics for optimization, automated negotiation techniques, and constraint satisfaction problem solving techniques. The resulting platform will outperform more traditional market products and services such as Freight Exchange Systems, Collaborative Platforms, Transport Control Towers or Routing Systems.

Project period: June 2018 – May 2021. **EU Funding received**: 5 million euro.

7.3.7 Other related EU sponsored projects

Some other project sponsored by the EU that touch the topic of horizontal collaboration are:

- Modulushka – standardized load carriers
- ICONET – Physical Internet framework
- iCargo - Open freight management ecosystem
- Secure SCM - lowering data-sharing risks in SC Collaborative environments
- Logicon – improving access to Logistic platforms to transport SMEs
- Discwise - integration of small and medium sized LSPs
- T-Scale - new business and operational models for vertical and horizontal cooperation

7.3.8 Reflection on European supply chain collaboration projects

As can be concluded from the previous sections, a lot of applied research has been done on the topic of horizontal collaboration. ALICE (2015) drew some Important lessons from these past projects:

1. Collaboration can be successfully triggered and applied in almost any logistics environment, but it does not occur spontaneously with the existing market players.
2. The new function of the Neutral Trustee developed in CO3, in addition to the existing roles of shippers and LSPs (3/4PLs), is essential in triggering and creating sustainable and large-scale horizontal collaboration in the logistics market.
3. Horizontal collaboration among the right partners (shippers) can deliver double-digit improvements in logistics cost, transport carbon footprint, empty mileage, network/asset utilization, and in many cases it also improves customer service levels.
4. Anti-trust compliant, multilateral legal agreements will be key in the creation of sustainable and large-scale collaborations. However, in most companies, there still exists a large mental gap between logistics and legal professionals.
5. Along with legal solutions, information technology (ICT) plays a crucial role in collaboration, but mostly as an enabler, not as a driver.
6. To ensure stability and fairness of the collaboration gain sharing and good governance between the partners are essential.
7. Many LSPs in the market are still hesitant or defensive to actively support collaboration between shippers or to embrace collaboration among themselves.

These lessons stress the promise of horizontal collaboration to contribute significantly to the vision of the EU and ALICE to improve logistics efficiency in Europe by 30% by 2030. However, despite the recent European projects on horizontal collaboration summarized in the previous section, a strong move of the logistics industry towards collaborative logistics is yet to be seen. Many projects have trouble gathering representative (real-time) company data to test their collaborative solutions. As a result, some projects remain technical or conceptual, whereas the ambition was to bring about many industry test cases. An example is the project Nextrust, which was a direct successor of the CO3 project. The claim of Nextrust was that the tools and concepts gathered and developed in CO3 are ready and the challenge is to apply it in as many industry sectors and with as many companies as possible. Although the budget of the project was 9 times bigger than CO3 (18 vs 2 million euro) and despite several temporarily successful pilot projects, Nextrust did not deliver the industry mind shift and the market take-up that it promised. This again illustrates the paradox also noted by Basso et al. (2019) that a logistics concept that is widely regarded as a necessary condition for achieving the policy and company goals of increased efficiency, is applied in practice only in very few situations. We will come back to this inconvenient truth when we discuss the Dutch collaboration projects in Chapters 8 and 9.

It seems that the actual problem with horizontal collaboration in logistics lies more on governance and scalability side of the solutions than on the envisioned savings. The required knowledge and insights are there and most of the shippers and LSPs are aware of this. But still companies are waiting for the 'golden' support model for horizontal collaboration to appear.

One problem is that usually companies must base their decision to participate in a collaboration on calculations based on static, historic data that is gathered for all the potential consortium partners. Currently, these data are not centrally stored and only available in companies' internal systems in company specific formats. The process of data gathering and harmonization usually takes a few weeks or even months, and by that time the situation has usually changed, and the calculations made do not fully apply anymore. Note that the mentioned Secure SCM and iCargo projects aim to solve this problem. But currently this still tedious process may explain why the current model of collaboration is not scalable, flexible, or sustainable.

There is a growing conviction also in the ALICE group that the attainable cost reduction through collaboration is apparently less than the perceived cost of the needed transition. This may change if the EU's green deal[21] goes ahead, if some other unavoidable external force comes to the stage, or if a specialized trustee or software company finds a silver bullet collaboration model. But until then, collaboration will probably stay a tough nut to crack.

7.4 SOME RECENT COMMERCIAL INITIATIVES

Despite the somewhat disappointing message of the section above, still there is a growing industry of companies specializing in horizontal collaboration support, trustee functions, collaboration software, Etc.

Trustees	**Collaboration software**	**Focused consortium**	**Control tower**
Digitrust	AX4	Fjordfrende	IDS
MixMove	Haulistix	Transmission	Informore
TriVizor	Mix-Move-Match	Netwerk Benelux	Shareship
	Nistevo	Spring Platform	Smartway Logistics
	Quicargo	Greenway Logistics	C6 / King Netherlands
	Stockbooking	Construction Hub Utrecht	
	Stockspots	Greenport Logistics	
	TGmatrix		
	Uturn		
	ChainCargo		
	Cargonexx		

Table 23. Commercial collaboration initiatives

Next to these commercial companies that have collaboration as their main business model, also an increasing number of LSPs are investing in proprietary control towers to connect internally and with their suppliers (i.e. carriers). All the major transport integrators (FedEx, UPS, DHL, etc.) have this in place, but also some smaller innovative LSPs are such Ahlers, FM Logistic, Geodis, and LINEAS are moving in this direction.

Some other companies are also making good efforts to enable collaboration. For example CHEP, the pallet pool company, is actively promoting and setting up collaborations between their customers. With their

[21] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

scale and access to transport flow data based on the tracked positions of its pallets, CHEP enables its customers to bundle their flows and reduce empty miles, fuel, $C0_2$ emissions and costs.

So, there are some interesting commercial initiatives fostering horizontal collaboration in Europe. In the next chapter, we turn our attention to the Netherlands, a frontrunner on the topic of horizontal collaboration. The Netherlands has stimulated it financially via a government program that ran from 2010 until 2020. It is instructive to see the experiences in the Netherlands, both its successes and its disappointments. The lessons learned are useful for commercial companies as well as for European and national policy makers.

8 CASE STUDY: THE NETHERLANDS

Van Laarhoven (2008) in his strategic logistics advice to the Dutch government explained why collaboration suits the Netherlands so well. The Dutch culture is defined by its internationalism and its focus on collaboration in the small geographical area it covers. This has resulted in the Dutch 'polder model'.

> This polder model (Dutch: poldermodel) is based on the acclaimed Dutch version of consensus-based economic and social policy making in the 1980s and 1990s. It gets its name from the Dutch word (polder) for tracts of land enclosed by dikes. The polder model has been described as "a pragmatic recognition of pluriformity" and "cooperation despite differences". It is thought that the Dutch politician Ina Brouwer was the first to use the term poldermodel, in her 1990 article "Het socialisme als poldermodel?" (Socialism as polder model?), although it is uncertain whether she coined the term or simply seems to have been the first to write it down. The current Dutch polder model is said to have begun with the Wassenaar Agreement of 1982, when unions, employers, and the government decided on a comprehensive plan to revitalize the economy involving shorter working times and lower wages on the one hand, and more employment on the other. This polder model combined with a neoliberal economic policy of privatization and budget cuts has been held responsible for the Dutch economic miracle of the late 1990s.

The polder model enables successful collaboration among entities with different stakes. This has happened a lot already in important Dutch industries such as agriculture where large and ambitious innovations are developed by close collaboration between companies, knowledge institutes and the government. In addition, the Dutch historic focus on international trade and its multilingualism make it possible to collaborate internationally.

Having funded or otherwise supported over 70 horizontal collaboration projects, both academic and business practice oriented, the Netherlands provides a rare and interesting case study on collaboration experiences and the adoption of 4C-like concepts. Despite the multi-million subsidies over the last ten years, an industry-wide adoption of 4C is still not yet happening in the Netherlands, and there is a long-running debate on the correct model for collaboration. Who should take the initiative? What is the ambition level? Across or within industries? Etc. In this chapter we will dive deeper into this Dutch case study with the aim to generate learnings for the Dutch and for other (European) countries considering to further stimulate horizontal logistics collaboration to achieve societal goals.

8.1 EARLY DUTCH COLLABORATION INITIATIVES

As we have seen in Chapter 5, it took until 2007 before more than four papers per year were published about horizontal collaboration in supply chains. In the Netherlands however, it was already regarded an important strategic direction for the logistics industry years before. The Dutch Ministry of Traffic and

Water management (2001) wrote that to support the economy, reduce congestion, increase quality of living and improve safety, the transport sector must be facilitated to bundle their freight flows. In the same report it was also concluded that pricing policy, such as toll per kilometer or a carbon tax) will be essential to reduce CO_2 emissions. Such measures will increase the marginal costs of kilometers driven and can be expected to strengthen the quest for transport efficiency through an increased adoption rate of technological innovations, but also through intensified transport collaboration initiatives. A third relevant recommendation in the report is to increase modal shift from road to rail and waterways. The authors state that this can be accomplished on the supply side through infrastructure investments (e.g. intermodal terminals) and on the demand side through increased bundling of freight flows to reach the critical mass to make multimodal transport a viable option from a cost perspective. Finally, the report mentioned the development of a so-called 'Logistics Datahub Netherlands (LDN)', a large central database maintained by an independent foundation where data on freight flows in the Netherlands would be stored in a harmonized way to facilitate searching for bundling opportunities.

Also, at the start of the millennium, the Dutch government commissioned a study into synergy effect of horizontal collaboration in transport and logistics, called SYLONET (SYnergies in Logistic NETworks). In their end report, Vos et al. (2003) elaborate on horizontal collaboration by defining three types of synergy: operational synergy, coordination synergy and network synergy. In Figure 46 these three types of synergy are illustrated.

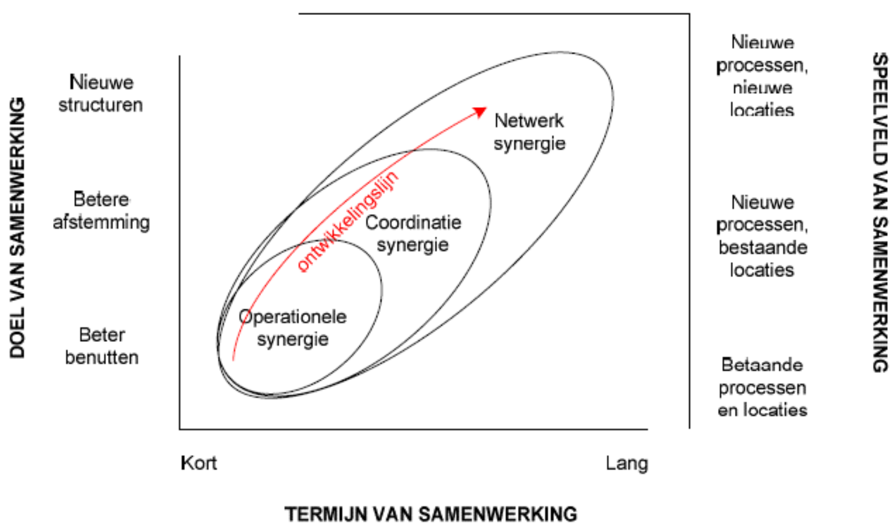

Figure 46. Collaboration types defined by Vos et al. (2003) [In Dutch]

In addition to the synergy definition, two examples from practice are described: 'Distrivaart' and 'Zoetwaren Distributie Nederland'. Distrivaart was a collaboration between a number of beverage manufacturers using inland shipping instead of trucks for the distribution to retail distribution centers. 'Zoetwaren Distributie Nederland' was a collaboration between several bakeries that jointly outsourced their distribution to one logistic service provider. SYLONET concluded that the specification and measurement of synergies is important, but fair gain sharing is also a prerequisite for successful collaboration. Their advice to develop adequate gain sharing mechanisms was indeed taken up in literature and currently there exists a significant body of literature on this topic (see Section 5.6).

Another project worth mentioning is the 'Koud' (Dutch for Cold) project in which three prominent shippers (Douwe Egberts, Masterfoods and Unipro Bakery) started a collaboration. The shippers bundled their flows of frozen products to joint customers such as catering companies, restaurants, and hospitals) to achieve cost reductions and service improvements. In the situation before the collaboration, each shipper operated its own distribution network in which FTL movements went from the factories to the distribution centers of three different LSPs who then distribute the goods. The collaboration project redirected all FTL movements to the distribution center of a single selected LSP who bundled the flows to the same customer or region. The reported savings amounted to 30% of overall transport cost.

8.2 The Top-sector Logistics (TSL)

To stay competitive in the globalizing economy, in 2012 the first cabinet of Prime Minister Rutte launched the so-called Top-sectors agenda to achieve the following three goals:

1. Have the Netherlands in the top-5 of knowledge economies in the world by 2020.
2. Increase Dutch spending on Research & Development to 2.5% of gross annual product by 2020.
3. Establish so-called 'Top-consortia' for Knowledge and Innovation (TKI) by 2015 where public and private partners together invest for more than € 500 million of which more than 40% is financed by companies.

In the period 2012-2015 the government invested about € 7 billion in nine top-sectors that were selected for their strategic importance for the Dutch economy now and in the future. These nine industry sectors are:

- High tech Systems and Materials
- Life sciences & Health
- Agri & Food
- Water
- Chemistry
- Horticulture
- Creative Industry
- Energy
- **Logistics**

The top-sector agenda aims at collaboration between companies, knowledge institutes and the government, but also at cross-fertilization between the various top sectors. For each top-sector, the government is striving for maximum returns from the provided tax incentives, loan guarantee schemes and direct investments. A large proportion of government loans and grants strategically go to SMEs and research institutes. Together, businesses and researchers have the task to create more innovation, build a stronger economy and devise solutions for tomorrow's challenges.

The logistics industry is one of the top-sectors selected. With an added value of around € 53 billion per year and more than 600.000 jobs, it is of great importance to the Netherlands. The top-sector Logistics (TSL) supports companies in many other industries as well, since in the Netherlands logistics is responsible for 8-18% of total costs on average[22]. Therefore, efficient logistics processes are key for many companies' competitive position. The TSL has defined an action agenda (see Topteam Logistiek, 2011) in which it formulated their strategy for the period 2012-2020. In short, this strategy means that in 2020 the Netherlands must have a leading position in 1) international transport flows, 2) orchestration of (inter)national logistics activities and 3) innovation and business climate. These strategic goals are translated into twelve concrete action agendas:

- Sustainability
- Neutral Logistics Information Platform (NLIP)
- Synchromodal Transport
- Trade Compliance and Border Management
- City Logistics
- **Cross Chain Control Centers (4C)**
- Service Logistics
- Promotion of the Netherlands abroad
- Simplification of legislation
- Human Capital Agenda
- Supply Chain Finance
- Freight corridors

8.3 The Cross Chain Control Centers (4C) action agenda

One of the action programs of the TSL concerns Cross Chain Control Centers (4C). By becoming a global leader in the development and staffing of 4Cs the Netherlands aims to reach a steady position in the top of global logistics. The definition of a 4C was already given on page 8 in Section 1.2. For a well-functioning 4C, optimal alignment between individual supply chain entities, in the Netherlands and internationally, is crucial. A 4C can be operated by an independent orchestrator, through distributed orchestration among partners, or even by a designated division of an LSP separated by a Chinese wall from the LSP's other processes. 4Cs can be organized in many different ways, based on different elements of the typology as shown in Chapter 6.3. However it is organized, the most important goal is to achieve seamless alignment between supply chain actors so that maximum value can be created across these supply chains.

High quality supply chain orchestration is considered an important competitive value for shippers. It makes the delivery to customers robust against supply chain disruptions, reduces cost levels and time-to-market, increases customer service, and overall improves the value of the product to the end consumer. Given the increasing complexity of logistics following the trends introduced in Sections 2 and 3, it becomes more and more difficult for (individual) shippers to achieve this level of excellence. Capitalizing on the centralized competences and expertise in 4Cs, supply chain orchestration can go beyond the mere

[22] https://top-sectorlogistiek.nl/wat-is-de-top-sector-logistiek/ [In Dutch]

coordination of transport flows by also providing services on joint forecasting, (big) data analytics, supply chain financing, etc.

Realizing the strong potential of 4C for the Dutch economy and logistics industry, the TSL has made significant investments in applied research into and applications of 4Cs. In the last ten years (2010-2020), a total estimated[23] subsidy of € 5 million was invested. The underlying idea is that horizontal collaboration is essential to achieve the efficiency improvements that are needed to realize the transport sector's contribution in abating climate change. 4C is a viable attempt to attach a business model to the (theoretical) concept of horizontal collaboration.

The question is justified what this government investment has brought to the Dutch economy. To answer this question, three actions will be taken by TSL. First, the quantitative KPIs of avoided road kilometers and reduced CO_2 emissions will be reported. Second, an inventory will be made of what indirect effects the action has brought to the Dutch economy beyond the boundaries of the actual projects sponsored by TSL. And finally, in this synthesis study, the goal is to evaluate the content of the projects conducted under the 4C action agenda, and formulate lessons learned from the past and recommendations for the future. These lessons for a large part will be based on experiences from the Dutch 4C projects that have been undertaken in the period 2010-2020. These will be discussed in the next section.

8.4 4C PROJECTS

TSL has funded many innovative projects since 2010. In total, over 70 projects in various industry sectors had a 4C label. With the help of TSL those projects that had 4C as their main theme and thereby particularly helped to further develop the concept of 4C were filtered out. These six projects will be briefly summarized in the subsections below, and in Section 8.4 some other Dutch projects with interesting insights for 4C will be discussed.

8.4.1 Project 4C4More

The first completed 4C project that was funded by TSL was called 4C4More and was extensively documented in book edited by De Kok et al. (2014). The project was initiated by Unilever and Kuehne Nagel in 2010. At the time, the dominant vision was that horizontal collaboration among LSPs was the best way to substantially lower transport costs: a shipper or retailer should not have a preference about whose truck delivers their goods, just like most people are indifferent about the bank that owns the ATM from which their money is collected. Kuehne Nagel teamed up with colleague LSPs Nabuurs and Bakker in a project supported by ORTEC, TNO and Technical University Eindhoven (TUE).

It was agreed that each LSP would make its own trips from the customer orders received, after which the trip would be uploaded to the ORTEC scheduling engine. This software tool combined trips and vehicles, so that empty mileage would be minimized, truck utilization improved and customer service

[23] Exact numbers are difficult to give since some (research) projects that have the 4C label touch the topic of 4Cs only peripherally.

requirements, e.g. time windows, would be satisfied. Data of a representative period were used for validation.

Given the thin margins in transport, the results of the pilot showed that collaboration between LSPs with a substantial market share in regional Fast-Moving Consumer Goods (FMCG) transport brings important reductions in costs, empty mileage, and overall mileage. On an annual basis, savings amounted to almost € 1.300.000, which easily offsets the investment associated with implementation of the LSP collaboration, estimated at € 800.000 in total. Furthermore, a 13% reduction in the number of vehicles needed to transport the goods was achieved. Based on these pilot results, the LSPs decided to take further collaboration steps taking into account Dutch and EU competition law (see Section 5.7). The perceived implications of this kind of legislation turned out to be one of the major factors that eventually stoppedthe commercial uptake of this structural collaboration.

In 4C4More, both economies of scale and economies of scope were considered as reasons for creating a 4C. If the competitive position of a company is determined by its ability to exploit economies of scale in (part of) its SCM activities, it seems appropriate to have 1) company-dedicated activities in the case of low economies of scale and 2) a combination with activities of the others in the case of high economies of scale. When economies of scope are concerned, one needs to carefully ensure that company skills can indeed be shared within the consortium. A 4C entity enables the exploitation of economies of both scale and scope: it can manage and execute supply chain activities of multiple companies, whereby its learning curve is steeper (economies of scope) and whereby it can ensure the most efficient use of scarce resources (economies of scale).

As stated, the 4C4More project focused on the FMCG supply chain, where collaboration between shippers, LSPs and retailers can create financial and societal benefits beyond those created by standard bilateral relationships. These complex relations require more sophisticated software tools and higher skilled SCM professionals. Under appropriate modeling assumptions, decision support tools should produce feasible and ’reasonable’ solutions that can be further improved by planners in the 4C who sometimes relax binding constraints if appropriate.

Project period: May 2010 – August 2015. **Subsidy received**: 1 million euro.

8.4.2 Project 4C4D

An important challenge for the Dutch logistics industry is the question how to improve the quality (e.g. carbon footprint and air quality) and quantity (e.g. transport movements) of the distribution activities of the different physical flows into cities. Indeed, ‘city distribution’ was one of the five key innovation themes reported by Van Laarhoven (2008) that came out of a roundtable discussion with senior representatives from the Dutch industry.

Especially in urban areas, there is a huge potential for bundling of distribution flows that are now fragmented. Although there are first signs of collaboration between LSPs and retailers, recent reviews show that there are hardly any examples of commercially successful and environmentally sustainable collaborative solutions in urban areas within Europe. The 4C4D research project aimed to investigate feasible collaborative supply chain designs, the associated business models and the critical questions of risk and revenue management, specifically in an urban context.

The focus of 4C4D is collaboration in the distribution and orchestration among LSPs and between LSPs and retailers, i.e. the bundling of physical flows into (urban) areas. Increased collaboration likely leads to innovative distribution concepts that are based on sound business models, while still meeting objectives and restrictions set by municipalities. 4C4D was especially relevant to the Dutch economy because the Netherlands has very densely populated urban areas. Hence, there is a strong sense of urgency among all parties to improve current distribution approaches. These solutions can act as best practices towards comparable areas in Europe.

One of the prominent solutions that are proposed for fragmented deliveries into cities is the use of one or more urban consolidation center (UCCs, see Section 3.3). As part of the 4C4D project, research was conducted into the optimal location of a UCC, the impact that such a UCC has on the cost structure in the supply chain, the policy measures available to stimulate UCC usage, the potential that UCCs offer to switch from combustion engines to electric engines, the potential to develop new services out of a UCC, and a number of successful UCC case studies in the Netherlands and other countries.

Despite of the arguable benefits, large-scale UCCs are not quite common yet. Apparently, there are more factors that influence the introduction and us of UCCs. In the project, research was done on the social aspects of UCCs and the often-conflicting interests of urban logistics stakeholders, for example:

- How can (competing) LSPs collaborate horizontally by exchanging freight, and what is a fair outsource price for this?
- What is the value of intelligent transport planning systems for the acceptance of UCCs?
- Can serious games convince stakeholders to pursue the joint goal of having a thriving city by sometimes sacrificing a bit of their individual profit?

Huijink (2016) wrote his PhD thesis as part of the 4C4D project. He analyzed a pricing-based collaboration structure in which companies form a coalition and then outsource orders to each other within this coalition for fixed outsource costs per order. These outsource costs consist of the fee that the other company receives for the delivery plus the costs for the additional inter-depot transport that is required. One of the most important decisions here is how to determine both the inter-depot costs and a fair fee. In this form of horizontal collaboration, the companies remain independent and decide for themselves which orders they outsource. This implies that, to determine the outsource costs that satisfy the preferences of the coalition, one needs to estimate which orders the companies are likely to outsource given the outsource costs. This stochastic process was also studied in the 4C4D project.

Project period: December 2010 – December 2015. **Subsidy received**: 706.000 euro.

8.4.3 Project DaVinc3i[24]

The Dutch floriculture sector is globally renowned. The sector has a huge impact on the Dutch economy, being the largest exporter of fresh products in Europe, the third largest exporter in the world with still

[24] Project description based on Van der Vorst et al. (2016)

significant opportunities for further growth. The sector wants to consolidate their position as the main (virtual) floriculture-trading hub in Europe and has therefore initiated the DaVinc3i project. DaVinc3i is the acronym for *Dutch Agricultural Virtualized International Network with Coordination, Consolidation, Collaboration, and Information availability* [25]. The project developed innovative logistics concepts supported by an information platform and collaborative business models. More specifically, the project investigated:

- The functional specifications for potential logistics coordination, consolidation, and collaboration concepts, with special attention for responsive quality driven logistics networks and synchromodal transport management.
- Opportunities for information exchanges and architectures to facilitate the advanced planning and control concepts developed in the project.
- Relevant collaborative business models that work for specific floricultural settings.

Throughout its history, the Dutch floriculture sector has been characterized by intense collaboration between all actors in the network. However, from a supply chain perspective still many logistics flows from source to sink are managed independently, resulting in inefficient transport. Flowers and plants are sourced internationally and might in the future, instead of being transported via the marketplaces in the Netherlands, be directly distributed via a logistics hub network in Europe to regional customers. More logistics collaboration between different actors in the chain, vertical as well as horizontal, may improve the efficiency of processes such as harvesting and transport, and reduce product waste. Key issue is that in a virtualized network, opportunities arise for different network configurations, for different routes and process configurations (e.g. where to assemble and pack), and for transport consolidation.

As part of the DaVinc3i project over 30 projects with business partners have been conducted. Based on those cases Van der Vorst et al. (2016) defined the following lessons learned relating to horizontal collaboration:

- Most chain actors in the floricultural sector are aware of new developments [such as horizontal collaboration] but are waiting to act until it is more urgent.
- Virtualization requires collaboration and synchronization of processes and information in the complete chain network.
- Responsive, high frequent delivery of high-quality cut flowers to the international market requires an international hub network with quality-controlled logistics principles. The added value of such an international hub network depends on collaboration: it requires high volumes and frequent flows to be cost efficient.
- Due to the advantages of consolidation, supplying to the nearest location is not always the cheapest.
- ‘One size fits all solutions’ for logistics concepts, IT solutions or business models will not work.
- ‘Trust is nice, control is better’: contracts are increasingly required to support collaboration between supply chain partners.

Project period: 2011 –2015. **Subsidy received**: 1.034.000 euro.

[25] www.davinc3i.com

8.4.4 Project 4C4Chem

A fourth 4C project sponsored by the TSL focused on the chemical industry. This sector is also a major player for the Dutch economy, contributing almost € 20 billion to the balance of trade in 2010 (51% of the total balance of trade goods). From a logistics point of view, the chemical supply chain accounts for about 10% of the transport flows (ton-km) in the Netherlands. Most of these flows are international, 19% by weight of all exported goods are chemicals. However, it is estimated that on average only 60% of load carrying capacity is utilized. This poor performance has several explanations, such as an imbalance between production and consumption areas, empty returns, a short-term focus in optimization and limited flexibility for the carriers to optimally plan shipments. While the first issue (imbalance) is hard to address from a supply chain perspective, the project 4C4Chem addressed the remaining three.

The Dutch chemical industry is not unique in its suboptimal logistics performance. About 10 percent of transport flows in Europe are caused by the chemical industry and due to large distances, relatively small volumes and sometimes inconvenient connections to preferred transport terminals, the transport efficiency is relatively poor. Therefore, there is a clear potential to increase transport efficiency through collaboration between producers, customers, suppliers, and LSPs to reduce waste in the chemical supply chains.

Horizontal supply chain collaboration in the commodity industry, such as most chemicals, might even have additional potential compared to other products since commodities are considered interchangeable (See Section 3.1 on standardization in logistics). 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.

Within the scope of the competitive situation of the European chemical industry, the project consortium anticipated that logistics capabilities and concepts are particularly relevant for the Dutch chemical industry, putting them in a better position to take full advantage of this. In 4C4Chem three innovative 4C-related approaches were applied to the supply chain planning process, being improved forecasting and planning of transport needs in the medium-term and improved short-term coordination between off-site and on-site logistics (PLAN), sharing of inventory and railcar resources (COMBINE), and bundling of transport flows (BUNDLE). Together these actions result in a showcase example of a 4C.

In 4C4Chem, relevant decision support models and new operating concepts were developed, evaluated and where applicable tested. In addition, the project partners developed a business model for LSPs to extend services in this sector, allowing the LSP to operate at a higher added value level if certain coordination activities are transferred to the LSP, for instance on-site logistics.

The chemical industry in the Netherlands does not have a rich track record of knowledge sharing about supply chain operations. Therefore, an important general objective is to use this project to establish a supply chain innovation community for the Dutch chemical industry and its associated logistics services.

Based on the results of four chemical case studies, 4C4Chem designed a business model for an independent `black-box' trustee entity named 4C4Com. 4C4Com enables structural horizontal collaboration between shippers of commodities in Europe. These shippers need to ship a commodity that is not mainly transported via pipeline. The total size of the shipments should be significant, at least initially, and the supply chains of shippers should be compatible. 4C4Com allows shippers to optimize logistic costs and CO_2. It collects information from all individual shippers and optimizes the entire logistics chain. This allows 4C4Com to physically bundle volumes, swap volumes geographically or to combine them by opening shared storage facilities.

Project period: September 2012 – December 2015. **Subsidy received**: 448.000 euro.

8.4.5 Project Construction Logistics (CL4C)

The construction industry in the Netherlands is relatively traditional and in most cases there is no structural logistics orchestration around building sites. Therefore, this industry has some catching up to do in the area of 4C, and with that in mind the Construction Logistics 4C (CL4C) project was started. Several 4C concepts were developed and tested at the participating companies in actual projects such as residential, utility and infrastructure construction sites. Construction-specific factors were combined with urban logistics elements since the most challenging construction projects usually take place in urban areas where people work, live and recreate.

CL4C ran for five years and its overarching goal was to develop specialized 4Cs for the construction industry. One of the key challenges was to make relevant information from all stakeholders centrally available. Based on gathered planning data of all individual companies a framework for orchestrated management of both information and physical flows was worked out using the Supply Chain Operations Reference (SCOR) model. This formed the basis for the further development of a 4C for construction logistics in CL4C.

Two prominent pilot projects were executed in Utrecht (project 'De Trip'), and in Amsterdam around the construction site of Hotel Amstelkwartier. The communicated goals of the 4Cs in these projects were the following:

1. Fewer transport movements and an improved vehicle load factor.
2. Consolidation of 'kitting activities' (work packages).
3. Improvements of the planning and the amount of ordered building materials.
4. Improve the management of waste.
5. Achieve a better consolidated planning of all companies active at or around the building sites.

Several innovative ICT systems to support the 4C were tested. The focus was on the coordination of the planning of individual companies to achieve a broader span of control for the 4C compared to the individually managed processes. The 4C must provide insight in the real-time planning of both construction and logistics activities in the complete supply chain from suppliers of materials to the workmen on the site.

It was concluded in CL4C that the integration of the various individual ICT systems can lead to a significant efficiency increase, but this will only be possible if the systems and processes are extremely user friendly and matched with the education level of the users on the site. Only then an orchestrated planning process can be widely accepted in the industry.

Project period: November 2013 – August 2016. **Subsidy received**: 977.000 euro.

8.4.6 Project Next level in logistics collaboration

Companies experience various barriers that hinder a wide uptake of logistics collaboration, such as not being able to find suitable partners, struggling to have enough mutual trust and the difficulty of aligning processes and practical difficulties during the implementation phase. In addition, the fear of violating competition law or incompatibility of ICT systems make that logistics collaboration is difficult until position. A consortium of knowledge institutes concluded that there is a need for structured exploration and development of the opportunities for collaboration among larger groups of companies. The project 'Next level in logistics collaboration' was carried out based on a shared ambition to overcome each of the above barriers and demonstrate possible steps towards actual logistics collaboration. The project consisted of the following four goals.

- Pilot 1: Bringing carriers and shippers together: bringing logistics together professionals using a Logistic Speed Dating app to find new ones initiate partnerships
- Pilot 2: Responsiveness: sharing information through an open and neutral logistics ecosystem earlier and easier to respond to current demand and available resources
- Pilot 3: Freight exchanges between three or more LSPs
- Knowledge sharing: disseminating the experience gained in the project, enriched with the knowledge from previous initiatives

The 'Next level in logistics collaboration' is based on the above three pilots that explore how data exchange via ICT tools can play a role in overcoming the barriers for collaboration. The goal is that based on these experiences other parties can accelerate realization of horizontal collaboration themselves. The project showed that it is wise to primarily focus on increasing efficiency in terms of kilometers driven and CO_2 emissions and only secondarily on showing that collaboration can improve customer service as well.

Project period: January 2016 – August 2017. **Subsidy received**: 291.000 euro.

8.4.7 Project COMPOSE

In the COMPOSE project, Tilburg University together with the industry association evofenedex is developed a digital platform where companies can easily get in touch with other to enter strategic logistical collaboration. COMPOSE focused on facilitating collaboration among shippers rather than between LSPs, so on producers and wholesalers that want to have their goods shipped more efficiently. To facilitate horizontal, innovative, and sustainable collaboration at a strategic level, this project takes a different approach than the other projects described in that it combines different kinds of academic knowledge such as:

- **Socio-psychological** knowledge on the do's and don'ts of stimulating collaboration.
- **Legal** knowledge on how to organize collaboration as well as the scope of the collaboration, what data companies should or should not exchange, etc.
- **SCM** knowledge on the logistics pro's and cons of collaboration.
- **Econometric** knowledge on the costs and revenues of collaboration and how to share them.

This multi-disciplinary knowledge is gathered on a digital platform where companies can be matched with potential partners after specifying their business profile and supply chain needs. Subsequently, companies can, either independently or together with sector association evofenedex, explore collaboration opportunities in logistics fields such as transport, warehousing, and human resources.

The COMPOSE project pays special attention to 'soft' elements of collaboration such as cultural backgrounds, personal fit, etc. The importance of these aspects were also discussed in Section 5.3 on Trust and commitment. Socio-psychological insights were used in the development of three tools: a matchmaking tool, a network matching tool, and an order matching document. A 'match' between shippers can for example occur when the companies face similar challenges or have similar logistics facilities and capacities.

On the level of personal characteristics, in COMPOSE an online system was developed to determine whether two persons interested in collaboration have a match for example based on ambitions and personal motives. In addition, a match between companies can only occur if the logistics profiles match as well. To determine the logistics profile, some high-level transport data must be shared through an order 'matching document'. This multi-step matching process aims at finding combinations of persons and companies that did not know each other before. Such a structured approach is expected to result in better results that the current situation in which matches are commonly based on good fortune and incidental encounters.

An interesting characteristic of COMPOSE is the active involvement of the industry association evofenedex. Such an entity is potentially very suitable to connect potential collaborators. An industry association is non-commercial and independent which creates more trust than in the more common situation in which the collaboration is encouraged by companies that in one way or another have a commercial stake in setting up collaborations. The matchmaking tool is still used by evofenedex to support collaboration among its members. The use of the network matching tool and order matching document depend largely on the way the collaboration is setup eventually, other tools already in use at companies could turn out to be sufficient.

Project period: October 2016 – October 2019. **Subsidy received**: 500.000 euro.

Now that we have the discussed the most important 4C project carried under the TSL research agenda, we are now ready to define some overall lessons learned in the next chapter.

9 SYNTHESIS

In the previous chapters we have reviewed the topic of 4C or horizontal logistics collaboration from a theoretical standpoint slowly towards a practical perspective. The goals of academia and industry are mostly the same: to improve the efficiency of transport and thereby contributing to important economic and sustainability goals. In this section we aim to synthesize this discussion by discussing fifteen propositions about 4C. The first eight are based on the initial expectations formulated by Van Laarhoven (2008) at the beginning of the 4C action program. The others are based on the description of the literature and 4C applications in chapters 5 to 8.

By qualitatively assessing the propositions we try to find common ground across all the 4C projects financially supported by TSL and to guide practitioners and policy makers on horizontal logistics collaboration into the most promising development paths. Table 24 provides an overview of the 15 propositions about 4C and horizontal collaboration. These were proposed to a group of eight Dutch and Flemish experts on the topic of horizontal collaboration, including the author. Using a Delphi approach the experts first individually scored each proposition. These responses were then collected and summarized. This summary was presented to and discussed with the experts in a joint meeting to arrive at a final judgement of every proposition.

	Proposition	**True**	**?**	**Not true**
1	A successful 4C does not only focus on the physical flow of goods, but also redesigns financial control, forecasting, and data management.	■		
2	4C has disrupted the logistics industry using new business models for existing and new companies that are now standard practice.		■	■
3	A 4C can be successful across industry sectors, it does not have to focused on a single industry sector such as fashion, electronics, fresh products, chemicals, etc.	■		
4	A 4C can be initiated from the shipper's side or the LSP side, but to be successful active participation of both sides is required.	■		
5	4C will strongly reduce the kilometers travelled in the Netherlands as well as the total CO_2 emissions from transport.	■		
6	A typical 4C project will become self-supporting (and profitable) within two years after the initial government subsidy		■	
7	Beyond the direct savings in kilometers and CO_2, 4C projects have a positive impact on the innovation level of the Dutch logistics industry.	■		
8	Horizontal collaboration in logistics has been 'over-studied'.			■
9	4C as a term has not caught and should be abandoned.	■	■	
10	4C is a means to an end.	■		
11	The full goals of the 4C program can only be achieved through direct government intervention such as a sufficiently high carbon tax.	■		
12	4C is a logical step in the development towards the Physical Internet.	■		

13	An intra-company control tower is the best way to develop a 4C.			
14	Governments should take an active role in coordinating specific collaborative logistics systems for example in city logistics.			
15	Academic research focuses too much on (methodological) subproblems, rather than on the bigger picture of how to achieve better transport efficiency.			

Table 24. Collaboration synthesis propositions

PROPOSITION 1

A successful 4C does not only focus on the physical flow of goods, but also redesigns financial control, forecasting, and data management.

This proposition is **true**. It must be noted that academic literature quite often motivates the concepts of horizontal collaboration by calculating cost savings from a quite limited scope, for example a joint route planning situation (see Section 5.2). And indeed, that is the purest motivation of why horizontal collaboration makes sense. In practice however, it is widely accepted that 4C-like concepts cannot only consist of redirecting and consolidating physical flows of goods. To achieve a commercially viable implementation of any of the collaborative transport models proposed by Palmer et al. (2019), i.e. co-loading, small delivery consolidation, consolidation centers, UCCs, multimodality, and logistics clusters (see Section 6.1.7), at least collaborative data management and some form of (automated) data exchange is required. This communication between consortium partners is key to the long-term success of collaboration and this key activity should normally be executed by a neutral trustee (see Section 5.4) or through technology such as a blockchain (see Section 5.5) that will facilitate future consolidation models as part of the Physical Internet. Once this data management and data sharing is reliably set up, it is a small step for a 4C to also take forecasts and other information such as contracts into account using centrally available supply chain analytics skills in the 4C. In that way, a 4C can truly add value to individual transport operations exceeding what logistics marketplaces (see Section 3.8) can offer. It was concluded by the experts that a 4C can only be successful if it is considered a safe and trusted extension of a company that helps to make logistics more efficient in any way it can by leveraging on broad collaborative opportunities.

PROPOSITION 2

4C has disrupted the logistics industry using new business models for existing and new companies that are now standard practice.

This proposition is **(possibly) not true**. This is maybe the same as asking if the glass is half full or half empty. It is certainly true that the high expectations formulated by Van Laarhoven (2008) and others in the early phases of the 4C program are not fully achieved. The overall quantified goal of reducing road transport by 50 million kilometers per year was not entirely reached. And the foreseen new transport orchestration industry has not yet developed to the size expected and did not yet disrupt the traditional model of mostly bilateral transport contract between shippers and LSPs. However, unquestionably things have changed as a result of the ten years of promoting and testing horizontal logistics collaboration. Examples of logistics collaboration are presented and studied in (applied) universities and the young professionals entering the logistics industry usually have a mindset that is much more open to collaboration beyond company borders (see Section 6.5.1). Therefore, today we see much more supply chain collaboration, better structured data exchange and overall improved skills of logistics professionals. The 4C program may not have delivered the ambitioned disruption of the logistics industry, but it did create a mind shift. Conferences on collaborative logistics are always well attended and serious attempts are made to bundle flows with other companies, today mostly motivated by sustainability goals. More and more companies are open to explore the opportunities by collaborative logistics. Traditional 4PL companies and other LSPs are also adding many elements of the 4C ideas in their own business model, for example by using platform technology as a way to initiate collaboration in an ad hoc manner Fully fledged 4Cs are still in the early phase of acceptance today, but indirectly it has certainly changed the logistics industry. These indirect effects will be the topic of another study by TSL that is yet to appear (see Section 8.3).

PROPOSITION 3

A 4C can be successful across industry sectors, it does not have to focus on a single industry sector such as fashion, electronics, fresh products, chemicals, etc.

This proposition is **true**. The definition of horizontal collaboration states that it deals with collaboration between companies that are active on the same level of different supply chains. This definition does not limit horizontal collaboration to applications within a single industry, and certainly not to combinations of direct competitors. Interestingly, when discussing horizontal collaboration with logistics professionals, often it is assumed that it involves collaborating and sharing information with direct competitors. Under this coopetition assumption (see Section 5.3), soon the discussion will be on NDAs, contracts, competition law, cost and gain sharing, etc. That is a pity, because horizontal collaboration can be just as beneficial when a consortium consists or businesses with compatible products (for example containerized flows or ambient palletized goods) from different industry sectors. Sometimes it even gives better possibilities for synergy when heavy-weight products are combined with voluminous products. Interestingly, four of the seven 4C projects discussed in Section 8.4 deal with collaboration within a single industry (FMCG, horticultural, chemical and construction). The reason is that these companies are historically focused on each other, traditionally as competitors and now slowly but surely also as possible collaboration partners. In addition, usually these industry partners have compatible products and sometimes also common customers and delivery addresses. As the 4C4D, Compose and Next level collaboration projects show, a 4C can also be instrumental to find and propose consortia that do not compete at all and are purely focused on improving logistics efficiency without this being contaminated by competitive hesitations. To summarize, an industry-focused 4C is perhaps the easiest to come up with as it more easily incorporates specific industry standards, but an industry-independent 4C can be expected to scale faster without running into competitive barriers.

PROPOSITION 4

A 4C can be initiated from the shipper’s side or the LSP side, but to be successful active participation of both sides is required.

This proposition is **true**. Gansterer and Hartl (2018) state that most academic papers focus on carrier collaborations. However, given the (methodological) focus of most papers on the increased optimization potential due to economies of scale from collaboration, for the theoretical insights it does not really matter whether carriers or shippers bundle the flows or shares assets. Induced by the sometimes disappointing long-term results of horizontal collaboration initiatives, in the policy area there has been a large debate over the question if the LSPs or the shippers are best positioned to start and lead the collaboration. Therefore, in Section 6.2, we added this topic to our extended horizontal collaboration typology. In the collaboration projects described, the first wave starting around 2010 was managed by LSPs (for example 4C4More), then there was a period were shippers took the initiative (4C4Chem) and recently focus seems to be an LSP collaboration again (Nextrust). Shipper collaboration makes sense because in the end the shipper are the cargo owners and they pay the bill for the transport. Furthermore, transport is not their core activity, so it is easier for them to make changes to it without competitive risks. On the other hand, LSPs are the actors that have most knowledge about the actual process of transport and are therefore better able to judge what is possible and what not. Whoever takes the initiative, experience has shown that an approach purely focused on either the shippers or the LSPs will not likely result in a successful and scalable 4C. The ambitious goals of the 4C concept require active involvement of both the buyers and the sellers of transport. The former pays the bill and will therefore always have the final say, and the latter is the specialist that knows what is possible and what not. Important here is to realize that from the start of a logistics collaboration, initiated either by an LSP, shipper or any other stakeholders, it needs to be clear that there is a good reason to start he collaboration anyway. When setting up the collaboration, eventually both LSPs and shippers need to be involved to some extent. This can be minimal (getting some freedom as an LSP to change routings, ETA's, etc.) up to more structural forms of collaboration which require a more detailed governance.

PROPOSITION 5

4C strongly reduces the kilometers travelled in the Netherlands as well as the total CO_2 emissions from transport.

This proposition is **true**. In addition to an ambitioned yearly € 1.8 billion added value to the Dutch economy, 4C is expected to reduce the kilometers travelled by road freight vehicles by 50 million and the accompanying CO_2 emissions by 50.000 tons, both per year. Studies by TNO and BCI (2018) have shown that transport kilometers by road in 2018 were reduced by 25 million per year, i.e. 50% of the target for 2020. Although this is quite far below the required 50 million kilometers saved per year, still it is a significant reduction. It was stated by the experts that 4C has developed at a slower pace than hoped for, but that its impact is growing slowly but surely. They are confident that 4C can scale up in the next years and that it will also benefit from a European wave towards transport innovation, efficiency and collaboration initiated by ALICE and the various projects introduced in Section 7.3. After all, efficiency increases through collaboration become more beneficial when distances driven are longer. Sometimes freight bundling requires additional stops at the origin or destination area of route. The additional costs from this must be offset by a cost reduction per kilometer from increased load factors. Therefore, the business case for horizontal collaboration will be more easily positive on long European hauls than on Dutch short distances. Experts also note that only looking at the efficiency gains in terms of CO2 emissions can be misleading. Of course from a societal point of view this is an important performance indicator, but form a company perspective the incentive to get involved in horizontal collaboration initiatives is more diverse. Sustainability has become an important incentive, but a more holistics view on the set of performance indicators (including costs, service levels, flexibility, etc.) is important to take into account.

PROPOSITION 6

A typical 4C project will become self-supporting (and profitable) within two years after the initial government subsidy.

This proposition is **unclear**. Although it was an explicit expectation of TSL that a subsidy covering start-up costs for commercial 4Cs would enable them to scale independently without further financial support, this has proven to be difficult. The projects in Section 7.3 (Europe) and 8.4 (the Netherlands) have sometimes resulted in sustainable collaborations that are continuing and sometimes even growing, while some other 4Cs that were set up in these projects were stopped soon after or even before the subsidy period ended. It is widely established that the start-up period of a collaboration is difficult. In Section 7.3.8 this hurdle was discussed. Companies must usually base their decision to engage in a collaboration on calculations based on static, historic data that is gathered for all the potential consortium partners. Currently, these data are not centrally stored and only available in companies' internal systems and in company specific formats. The process of data gathering and harmonization usually takes a few weeks or even months, and by that time the situation has changed, and the calculations made do not fully apply anymore. Currently this still tedious process may explain why some models of collaboration are not scalable, flexible, or sustainable. On the other hand, as discussed in Section 7.2, it is also true that once a collaboration initiative runs, significant savings can be realized: payback periods shorter than six months are no exception. It should be noted that if a commercial trustee is used in the 4C, their costs also must be funded from the cost savings achieved. It is fair to say that given the diversity of 4C initiatives that are supported, with all their own dynamics, it is not possible to give a 'golden-rule' for becoming a successful self-supporting organization.

PROPOSITION 7

Beyond the direct savings in kilometers and CO_2, 4C projects have a positive impact on the innovation level of the Dutch logistics industry.

This proposition is **true**. The matter of innovativeness and absorption capacity of the logistics industry has been discussed in Section 4.6. Van Laarhoven (2008) already stressed the importance of the Dutch logistics industry as a global leader in new logistics concepts and services. That is also apparent from the TSL ambition to have a steady position in the top-5 of the world logistics performance index. Like with the ambitions for reductions in CO_2 emissions and kilometers driven, also this ambition was not fully realized, but almost. In the latest release of the performance index in 2018, the Netherlands were in 6th place, after Germany, Sweden, Belgium, Austria, and Japan. Overall, Europe is doing very well on this ranking. In the top-10 only two countries from outside Europe can be found, see Table 25.

Country	LPI Rank	LPI Score	Customs	Infra	Int'l ship-ments	Logistics comp.	T&T	Timeli-ness

Germany	1	4.2	4.09	4.37	3.86	4.31	4.24	4.39
Sweden	2	4.05	4.05	4.24	3.92	3.98	3.88	4.28
Belgium	3	4.04	3.66	3.98	3.99	4.13	4.05	4.41
Austria	4	4.03	3.71	4.18	3.88	4.08	4.09	4.25
Japan	5	4.03	3.99	4.25	3.59	4.09	4.05	4.25
Netherlands	6	4.02	3.92	4.21	3.68	4.09	4.02	4.25
Singapore	7	4	3.89	4.06	3.58	4.1	4.08	4.32
Denmark	8	3.99	3.92	3.96	3.53	4.01	4.18	4.41
United Kingdom	9	3.99	3.77	4.03	3.67	4.05	4.11	4.33
Finland	10	3.97	3.82	4	3.56	3.89	4.32	4.28

Table 25. Logistics Performance Index 2018 [Source: https://lpi.worldbank.org/international/global]

The 4C program has brought significant advances in logistics innovation. An important side effect of collaborative efforts is that knowledge is shared among persons and companies in the same industry that did not interact regularly on a professional basis about common issues before. This was for example true in the 4C4Chem project (See Section 8.4.4) where the consortium members used the project also to establish a supply chain innovation community for the Dutch chemical industry and its associated logistics services. In addition, over 200 MSc students and more than 25 PhD’s have graduated on a research as part of a 4C project. These students will for a large part become professionals who will bring their collaborative knowledge and attitude into the logistics industry. An interesting remark regarding the relation between innovation and 4C was made by one of the consulted experts. If it is true that 4C and collaborative logistics networks are a steppingstone towards the Physical Internet (see proposition 12), logistics will be strongly commoditized in the years to come. This would mean that from the traditionally managed supply chains of today, via a phase of collaborative supply chains with a large demand for innovative solutions, the result will be a strongly standardized and automated logistics network that might not need much logistics innovation anymore.

PROPOSITION 8

Horizontal collaboration in logistics has been ‘over-studied’

This proposition is **not true**. Sometimes in the Dutch logistics industry there is some criticism that subsidized projects on 4C and collaborative logistics in general are too much focused on academia. It is argued that most important academic insights are already there and that focus should be redirected to market uptake and upscaling. A similar argument states that the relevance of applied research such as 4C should really be dependent of industry adoption. Surely, there is an element of truth in there, but it is also true that there is a broad agreement (in fact, the Paris agreement) that the current efficiency level of the logistics industry is not sustainable. Although 4C has not yet been adopted very broadly in Europe and the Netherlands, a tipping point caused by government policy or new disruptive business models (see Section 3.5) might not be far away. Once that happens, all knowledge on how collaboration can be used to improve logistics efficiency is extremely relevant. Therefore, it is considered a good development that academic research on collaborative logistics increases year by year as we saw in Chapter 5. Of special interest is research on suitable business models for 4Cs and behavioral aspects of the move towards increased collaboration in supply chains. As the COMPOSE project has shown focus is needed on the socio-economic factors influencing the strengths of a collaboration. It is relatively new that academics have added this field of research. A more multidisciplinary approach is required and in these areas there are certainly still some important gaps in literature.

PROPOSITION 9

4C as a term has not caught and should be abandoned.

This proposition is **perhaps true**. "*What is in a name? That which we call a rose, by any other name would smell as sweet" (Romeo and Juliet, by William Shakespeare).* Collaborative logistics terminology was discussed in Section 5.1. It can be concluded that 4C as a term has not caught in literature and in practice only to a limited extent. Although some companies now explicitly offer '4C services'[26], this is still an exception to the rule. In academic literature, a search on 4C or Cross Chain Control Center, does not give a single hit. On the other hand, there is nothing wrong with using the term 4C as it nicely covers its meaning. In the end, it does that matter very much how logistics will be made more efficient, as longs as it happens. And some form of collaboration will play a part in achieving that. This will be further discussed with the next proposition.

PROPOSITION 10

4C is a means to an end.

This proposition is **true**. If tomorrow the Dutch logistics industry would have hundreds of successful 4Cs, but the CO_2 emissions and the number of ton-km's driven on the road stay the same, nothing will have been achieved. The only reason to invest in the 4C concept is that it is believed that it will bring significant changes in these two main KPIs. The Paris agreement, the Green Deal, ALICE's roadmap of sustainable transport, they all have same goal, which is to make the global economy sustainable and safeguard our standards of living for the next generations. To do so, CO_2 emissions must go down sharply. If this can be achieved without new business models for logistics collaboration, that is a good result as well, although this seems unlikely. Companies looking for horizontal collaboration will need a strong motivation to do so. It turns out that only a clear cost reduction incentive, in many cases is not enough. Sometimes 4Cs are initiated collaborations are started for other reasons, like achieving better performance to customers in terms of service levels. It is expected that external influencing factors, like closing down city centers for non-zero-emission vehicles, congestion charges or supply chain disruptions cause by a pandemic, might turn out to be the incentive for business to engage in horizontal collaboration initiatives, simply because they need to. Therefore, policy makers should always critically assess which approach seems most promising and guide research funding and subsidies in that direction.

PROPOSITION 11

[26] See for example: https://www.idsnl.com/products/4c-solutions/

The full goals of the 4C program can only be achieved through direct government intervention such as a sufficiently high carbon tax.

This proposition is **true**. However, it is a difficult proposition to judge since answering it depends on one's political beliefs about the desired role of governments. Still, also after consultation with the expert group, it can be said with some confidence that without additional regulations or other forms of direct government intervention it is difficult to see how the logistics industry can accomplish the big efficiency leap that is needed to reduce their emissions by 30% until 2030. Ten years of experience with stimulating horizontal collaboration have shown that despite of sometimes evidently positive business cases there is a general reluctance to start collaborating. There may be various reasons underlying this, from human behavior (hesitation to lose perceived control of one's supply chain) to practical considerations (it is easier to prioritize internal efficiency improvement projects). Whatever the reasons, compared to other industry sectors, logistics is lagging in terms of sustainability improvements and innovativeness. The cases where collaboration did succeed usually had strong external motivations underlying it. For example, the case described by Cruijssen et al. (2014) where French food four retail companies decided to bundle flows, was successful because these companies were forced by their powerful joint customer (the retailer) to only deliver in full truck loads. There are also examples of city logistics where collaboration is forced by local governments by means of restricted vehicle permits in the city centers. Another stimulus for collaboration and bundling is the growing shortage of truck drivers in Europe. The most effective external motivation however will be of a monetary nature. To really change behavior, a flat carbon tax seems a logical step. If policy is aimed at reducing CO_2 emissions the simplest action is to make the production of it more expensive, like was done for tobacco, alcohol, ammonia, and other products that have negative side effects. If a carbon tax were introduced, this would improve the business case for making transport more efficient through collaboration a lot. Obviously, there are many implementation issues and decisions to be made if a carbon tax was to be introduced, but these fall outside the scope of this study. Taxing is a completely different approach than the current TSL approach of indirectly stimulating the desired behavior of collaborative transport by supporting pilot projects, hosting conferences etc. Taxing is a more blunt instrument that unfortunately could very well be the most effective instrument policy makers have.

PROPOSITION 12

4C is a logical step in the development towards the Physical Internet.

This proposition is **true**. Given the promising first results of simulation studies and case studies of the physical internet, a lot of attention has been centered around the likely transition towards the PI, i.e. how, when, and where will it emerge. Horizontal collaboration, albeit implicit, is a necessary ingredient of the transition towards the Physical Internet. Transport flows that were traditionally organized independently will be combined from a staffed central consolidation center (i.e., a 4C) first, and perhaps by a powerful routing algorithm for the PI in the future, like happens today for the digital internet with TCP/IP.

From a bird's eye perspective, the current set of logistics services is a suboptimal patchwork of commercial networks of various sizes, which strongly limits overall transport efficiency. Furthermore, the fragmentation of information flows and the heterogeneity of IT systems across various supply chains make it difficult to swap movements between LSPs. According to the ALICE roadmap, the PI should be realized by 2040. The climate agreements made in and between EU member states will probably play an important role in how fast exactly PI will be established. As argued above, when transport gets more expensive due to emission charges, there will be a stronger incentive for LSPs and shippers to make transport more efficient, and based on an obvious way to do this would be to bundle flows by routing them through major hubs and via highly efficient long-distance corridors. Such a development can be a strong enabler for the PI (Cruijssen, 2019).

The timing and pace of the transition from traditional transport to the PI aside, it can be expected that the industry will go through several phases before arriving at the PI. A lot of research has been done about these intermediate states that the logistics industry will see toward the PI. Notably, the EU funded SENSE project (2019), has provided a roadmap plan for the PI that consists of five phases, i.e. the current situation and four maturity levels (or 'generations') of the PI. Figure 17 shows that from 2030 onwards all main logistics networks are expected to interact with each other and offer services as a whole: a network of networks. The 4C concepts experiments with this. Without a definitive design of the communication standards, transfer pricing, automation, etc. that are key elements of the mature PI, 4C can accomplish the same goals in a smaller, customized, still more people-driven, and closed user group setting. The goal of course is that this can be scaled up to ever bigger collaborative networks, until the point that really it is not collaboration anymore but seamless supply chain integration. In that way, PI is the automation of 4C.

PROPOSITION 13

An intra-company control tower is the best way to develop a 4C.

This proposition is **not true**. The idea however makes a bit of sense. Nettsträter (2019) states that already in generation 1 of the PI it is expected that major LSPs and forwarders will develop internal connections between their departments responsible for different modes, as such achieving so-called 'physical intranets'. These internal networks will be an important laboratory to test more advanced inter-organizational collaboration. Intra-company experiences will be of great benefit to true horizontal collaboration projects among different companies. After all, when operating companies within a multinational have separate profit and loss accounts, they are likely to show the same behavior as stand-alone firms. The big disadvantage of intra-company collaboration however is its limited view on industry-wide roll-out and its understandable tendency to incorporate company-specific details. As discussed in Section 6.2.5 for industry specific collaboration, also intra-company collaboration projects are usually motivated in an ad-hoc manner because one or two individuals see a potential to reduce cost or emissions by improved orchestration. Such a collaboration usually is a one-off exercise that helps the company to achieve its optimization goals. On the other hand, collaborations that are initiated by companies that have collaboration support as their business model have the explicit ambition to provide a solution that works for every industry. Typically, these solutions are more software/technology-based initiatives that are aimed at a pool of potential users that is as big as possible.

To summarize, intra-company control towers have a higher probability of success, but generic 4Cs are expected to have a bigger overall impact on the industry than the many successful company-specific control towers.

PROPOSITION 14

Governments should take an active role in coordinating specific collaborative logistics systems, for example in city logistics.

This proposition is **true**. Although this is a quite general proposition, there are a few areas that are very suitable for direct government intervention. For example situations where too many stakeholders are involved that organizing regular discussions with all these stakeholders to discuss optimal collaboration models is not realistic. Cities and urban areas are prime examples of this. LSPs delivering shops in inner cities cannot effectively bundle their flows if every shop requires different delivery times or if the permit system of the local government does not support it.

At the same time, especially in cities, the rise of on-demand logistics puts serious pressure last-mile delivery systems. Today, the industry even promises instant (within the hour) delivery and cities are confronted with the negative consequences of this. Therefore, urban planners, city authorities and business stakeholders need a sensible collaborative approach to restrain the negative impact of the many fragmented deliveries that occur every day. A good example of a local 4C with active government participation is the project regarding construction logistics discussed in Section 8.4.5. A big construction site in a city affects almost everybody active in the city (inhabitants, shop owners, bars, tourists, etc.) are therefore calls for (public) orchestration.

PROPOSITION 15

Academic research focuses too much on (methodological) subproblems, rather than on the bigger picture of how to achieve better transport efficiency.

This proposition is **perhaps true**. In Chapter 5 we have seen that academia has given increasing attention to horizontal collaboration in supply chains. Whereas in the beginning of the millennium only three papers *per year* on the topic were published, in 2019 this was already more than one paper *per week*. Incidentally or not, the start of the rise in published papers per year coincided with the launch of the 4C program in the Netherlands. It is apparent that in scientific literature, much attention is given to quite specific (methodological) elements as surveyed by Gansterer and Hartl (2018), but very few publications focus on the more general organizational and business model aspects. Likewise, most attention is given to short-term collaboration (auctions) instead of more longer-term collaboration under a 4C-like setup. One explanation for this phenomenon is that academic research is used to focus, to have their papers accepted for publication in academic peer-reviewed journals. Usually, it is easier to prove that a new algorithm or gain sharing rule is novel and original, than it is to argue the innovativeness of a new business model or collaboration concept. This is a pity since the challenge for the logistics industry is to become much more efficient fast. And without being forced by legislation or taxes, this can only be achieved if successful novel business models are applied throughout the industry. Arguably, it would be helpful if next to the operations research area, also operations management and policy researchers and even psychologists or sociologists would come up with additional innovations to improve transport efficiency through collaboration and behavioral change. The COMPOSE project discussed in Section 8.4.7 is an interesting example of such a multi-disciplinary effort.

10 CONCLUSIONS

In this chapter we will round up our discussion of 4C and horizontal collaboration by formulating some main conclusions based on the previous chapters.

Sustainability as the underlying goal

4C is a means to an end. The only reason to invest in the 4C concept is that it is believed that it will bring significant changes in these two main KPIs. This might be an explanation for the sometimes disappointing success of some articulated collaboration projects: they might have conveyed a somewhat distorted message. The positioning of a project is clearly important. A project positioned as ‘aimed at collaboration’ will be more difficult to fund within a company than a project ‘aimed at reduction of costs and emissions’, while they could be the exact same projects. In Chapter 2, we have discussed a number of recent logistics developments that impact collaboration in the logistics industry. Most often, these developments are aimed at improving efficiency and as a result reducing the negative impact of transport on our climate. In the end, transport is not a goal in itself. It enables consumption, it does not generally improve it: a product is produced at location A and will be consumed at location B, all transport in between should be minimized, as well as the emissions that come with it. The Paris agreement, the Green Deal, ALICE’s roadmap of sustainable transport, they all have the same goal, which is to make the global economy sustainable and safeguard our standards of living for the next generations. The transport industry will play an important role in achieving this ambition.

Finding and recognizing the right incentives

What is the real incentive for business to start collaboration. Before looking into the opportunities of collaborative logistics it must be very clear for companies that it helps them in achieving their mission and their goals. For the more ambitious forms of 4C the incentive ‘cost reduction’ alone is not enough to move towards collaboration. Companies might see the opportunities, but at a very early stage they also see many hurdles (internal or external). For these, more complex, forms of collaboration a more holistic approach with a clear set of collaborative incentives is needed. For many companies the first steps towards collaborative logistics need to be presented in a very straightforward manner. Many companies do not have the resources to easily make a first step. Providing easy to use tooling or external services which look for collaboration opportunities (for instance through platform technology) on their behalf turn out to be successful. Another way of looking to incentives is that market circumstances will automatically lead to more structural forms of collaboration. In recent days we have seen collaboration between shippers being setup due to COVID-19 disruptions in their supply chains. Sustainability imposed by government regulations are also an external influencing factor enabling the further uptake of collaboration. In any case, the sense of urgency must be very explicit to serve as a trigger to move towards collaborative logistics.

Practice vs theory: an inconvenient truth?

Collaborative logistics has become a hot topic in all kinds of media, ranging from rigorous academic journals to mainstream- and social media. In addition, numerous case studies and analyses have shown the great potential of 4C and horizontal collaboration to reduce cost and emissions and improve service levels and robustness. Undisputedly, collaboration works in theory, but long-term and scalable success in practice has proven to be difficult to accomplish. As noted by Basso et al. (2019) and others, this can be explained by the practical difficulties in the areas of collaboration design, planning and operations, market circumstances and managerial behavior. In addition, it can also be that most of the publications on collaboration are relatively often written by 'believers', i.e. people who in principle have a positive attitude towards horizontal collaboration. With all good intentions, their contributions are meant to stimulate collaborative behavior in SCM, although sometimes by pointing out to the challenges and disappointments. Even more than in academia this holds for subsidized collaboration projects as usually in the project proposals the consortium members commit to a certain measure of success.

The Netherlands as a supply chain collaboration front runner

As we have seen in Chapter 5, it took until 2007 before more than 4 papers per year were published about horizontal collaboration in supply chains. In the Netherlands however, it was already regarded an important strategic for the logistics industry years before. The Dutch Ministry of Traffic and Water management (2001) already wrote that to support the economy, reduce congestion, increase quality of living and improve safety, the transport sector must be facilitated to bundle their transport flows. In the same report it was also concluded that pricing policy, such as toll per kilometer or a carbon tax will be essential to reduce CO_2 emissions. Such measures will increase the marginal costs of kilometers driven and will strengthen the quest for transport efficiency through intensified transport collaboration initiatives. The term 4C was coined in 2008 already and since then both the number of academic publications and the number articles in mainstream media and industry journals have increased rapidly. The importance of collaboration was further established in the implementation agenda of the Paris Agreement. It is clear from the literature review in Chapter 5 and the applications discussed in Chapters 7 and 8 that horizontal collaboration is needed to achieve the contribution in abating climate change that is expected from the transport industry. The Dutch idea of a 4C is a good attempt to attach a viable business model to the concept of horizontal collaboration.

The role of the new giants

In Section 3.5 we have discussed the so-called 'Amazonization[27]' of logistics. In a way this is an alternative for collaborative logistics and 4Cs. Bundling of flows and efficiency of transport is reached by the sheer size of the dominant company. Although this might be beneficial for a few macro logistics KPIs, this comes with several threats. First, one single commercial entity will control transport, see buying behavior and own loads of consumer data. This renders this company powerful and difficult to regulate for governments. In an extreme scenario, the fragmented transport industry may even develop into an oligopoly or in the end a monopoly which is not in the best interest of consumers. It also makes it

[27] Note that this is not limited to Amazon. Peers like Alibaba or Uber have similar ambitions.

impossible for SME transport entrepreneurs to do business as they cannot compete against the dominant player. Under a 4C concept these disadvantages are not there, but if it takes too long for 4Cs to establish the Amazons may have gained a deciding advantage. Therefore, it is good to keep focusing on strengthening the Dutch and European logistics industry by stimulating horizontal collaboration and other innovations.

Automation and the Physical Internet

Technology is developing rapidly and will keep changing the logistics industry in the years to come. This makes control tower concepts with a (much) smaller required human workforce per 1000 operated truck more viable. Technology in the end might make collaboration concepts unnecessary or implicit in normal planning operations. In line with roadmap of ALICE in Figure 17 this development will culminate in what we call the Physical Internet (PI). Today, PI is still a concept, not a reality. But if PI will become the new standard in future logistics it most likely will be realized in a gradual process where global supply networks evolve through three subsequent stages:

1. Fully owned supply chains, where the assets and services are key constituents of the company products/services, as differentiators for the customer. This is the current situation.
2. Horizontal collaboration and vertical coordination in a limited network of companies, sharing what are considered 'commodity' assets and services.
3. Physical Internet for most goods, in a collaborative network involving many parties who are implicitly collaborating, with the lowest costs and maximum availability and service level.

From step 2 onwards, the PI has many commonalities with the 4C concept. Whereas the PI originates from a mostly technical idea, 4C focusses more on the organizational or business model questions around collaborative and integrated logistics processes. In a way, the PI is the automation of a 4C, and 4C a business model within the PI.

Collaboration and trust

Trusts manifests itself at inter-personal, inter-group, inter-organizational and inter-network levels (see Section 5.3) and all of these areas should be carefully considered to make a collaboration work. This is especially important when collaboration takes place between competitors. In such cases, the interaction between the collaborators is referred to as *Co-opetition*, which is a whole research area on its own. Coopetitive interfirm relationships differ from collaboration between non-rival partners on several important aspects. Collaboration between competing firms is marked by inevitable tensions generated by the conflicts between (1) cooperative intent in a jointly run project and inter-partner rivalry in the broader market, (2) collective efforts at creating value in a partnership and competitive attempts at capturing the outcomes of collaboration, and (3) the need to invest intellectual resources into common activities and the necessity to protect the firm's knowledge and other intangible assets from appropriation by rivals.

This stresses the importance of a careful implementation of collaborative concepts such as 4C. A one-size-fits all solution will be difficult since every application area will have its own peculiarities. It is therefore important that trusted specialist guide companies through the process of setting up collaborations. In the absence of specific legislation or prohibiting costs of inefficiency by means of a high carbon tax, collaboration initiatives will need long-term care and attention to remain competitive.

Can we learn to collaborate?

In the western world, generations of students have learned in their industrial economics classes how competitive behavior can help companies reach their goals (Section 6.5.1). Concepts such as predatory pricing to push competitors out of the market, profit maximization by monopolists, first mover advantages, etc. are all examples of rather reckless competition that are extensively studied. Much less attention is given to how companies can work together to pursue common goals. And once working for a company, often personal and company targets reestablish the importance of outperforming your competition. In that sense, horizontal collaboration is a true paradigm shift that deserves strong government support. Although the current generation of secondary school and university students learn much more about the benefits collaboration and despite the support of TSL to make horizontal logistics collaboration work, it to be expected that still it will take some years before collaboration will be commonplace in the logistics industry. Slowly, but surely, it will happen.

Data-driven and data-hampered

A lot of formal research has been conducted on the topic of horizontal collaboration. In the first four months of 2020 alone over 30 academic papers about it have been published. It seems however that the actual problem with the acceptance of horizontal collaboration in logistics lies more in the governance and scalability area than in the calculation of the envisioned savings. The required knowledge and insights are mostly there and most of shippers and LSPs are aware of it. But still companies are waiting for the 'golden' support model for horizontal collaboration to appear. One problem is that usually companies must base their decision to participate in a collaboration on calculations that use static historic data that is gathered for all the potential consortium partners. Currently, these data are not centrally stored and only available in companies' internal systems and in company specific formats. The process of data gathering and harmonization usually takes a few weeks or even months and by that time the situation may have changed, and the calculations made do not fully apply anymore. As Van der Vorst et al. (2016) in their evaluation of the DaVinc3i project on collaboration in the transport of (perishable) flowers put it: "also information has a best-before date". It is worth noting that European initiatives such as Secure SCM and iCargo aim to solve this problem.

11 RECOMMENDATIONS

The performance of the logistics industry in general and of innovative concepts such as 4C does not only depend on actions taken by LSPs and shippers, but also on government regulations and advancements in scientific knowledge. In this final chapter we will formulate some recommendations specifically for three stakeholder groups, namely business, governments, and academia.

11.1 FOR BUSINESS

In Section 6.5 we have reviewed many qualitative recommendations that will increase the probability of success for companies considering engage in horizontal collaboration. In this section we will provide some additional insights and recommendations for business based on the literature and projects discussed in the other chapters.

Business case and payback period

Engaging in horizontal collaboration means the adoption (and sometimes still the development) of new business models that allow flexible orchestration of transport processes. Although there is a lot to gain from collaboration, the sheer fact that classical top-down in-company communication and management structures do not apply means that implementation will likely take longer than regular supply chain optimization projects within a company. Therefore, companies should expect and accept somewhat longer payback periods and should invest relatively much managerial effort in horizontal collaboration projects.

The ‘SLA curse’ of traditional transport tendering

In Section 5.8 we discussed synchromodality. Under this concept, the shipper determines in advance only basic requirements of the transport such as costs, duration, and sustainability aspects. Thus, transport processes can be better optimized and available resources sustainably and fully utilized. Synchromodality is a nice example of an enabler for 4Cs. If a 4C gets the freedom from a shipper to pick the most beneficial mode of transport depending on actual availability, prices, and timings. the 4C gets much more freedom to leverage its broader view across supply chains to increase efficiency. This will require some additional flexibility of transport buyers who all too often strive for control and strict guidance over logistics execution, instead of flexibility and trust.

Communication of best practices

To enhance industry uptake, it is important that businesses share their success stories around horizontal collaboration. Next to the more theoretical examples from literature, real cases are convincing in other ways. At TSL, there is a conviction that a lot of horizontal collaboration in taking place ‘under the radar’. In a follow-up to this synthesis study, an effort will be made to also discover more of these cases, but also companies are recommended to openly share their experiences, good and bad, so that others can learn from them.

Standardization

It was argued in Section 3.1 that standardized modular packaging and boxes can facilitate co-loading with goods from other shippers and as such make collaboration easier. This also applies to pricing systems, vehicle dimensions, load carriers, legislation, IT systems, data standards, transport documents, etc. (see for example Van Breedam and Vannieuwenhuyse, 2018). Standardization facilitates collaboration and the industry is strongly advised to reach an agreement on standards.

11.2 For academics

Business and governance models

With the upcoming EU Green Deal, a tipping point for large scale collaborative transport deployment might not be far away. Once that happens, all knowledge on how collaboration can be used to improve logistics efficiency is extremely relevant. Of special interest is research on the most suitable business models for 4Cs, and behavioral aspects of the move towards increased collaboration in supply chains. In these areas there are certainly still some important gaps in literature.

SENSE (2020) also states that there is still a need for the identification and definition of business models for the collaboration and interconnection of main European transport nodes. After all, the challenge for the logistics industry is clear: it must become much more efficient fast. And without being forced by legislation or taxes, this can only be achieved if successful novel business models are applied throughout the industry. Arguably, it would be helpful if next to the operations research area, also some more multi-disciplinary research will be conducted improve transport efficiency through collaboration and behavioral change.

Integration of vertical and horizontal collaboration

The integration of horizontal and vertical collaboration was also identified by Gansterer and Hartl (2020) as a major direction for future research in collaborative logistics. They observe that research in the field of centralized collaborations usually considers either vertical or horizontal collaborations. Generally, collaborations in large multi-layered logistics networks have not been researched sufficiently yet. We advise to do this, as it will be important to have a collaborative market that exceeds the local playing field of horizontal collaboration between a limited number of shippers or LSPs. As we have seen before, 4Cs can be more effective if also suppliers and customers are engaged so that they can adjust their service level agreements to enable much more efficient collaborative transport.

In a world of global supply chains, increased transparency and a global responsibility to reduce CO_2 emissions, it does not make much sense to limit collaboration to local consortia of companies that are active on the same level of the supply chain (horizontal collaboration), just as little as to limit our attention to supply chains of single products (vertical collaboration). We need a networked solution extending from raw materials to final products, and across all industries.

Impact of standardization

An important impediment to horizontal collaboration at large or 4C in particular (See section 7.1) is that it is very difficult to combine goods from various industries into the same vehicle, vessel or train, because of specific characteristics of the products and the load carriers used. Whereas this issue is mostly solved for collaboration within specific industry sectors (ref. ISO pallets, (refrigerated)containers, etc.), absence of logistics standardization is still a large hurdle for collaboration across industries. Although the definition of standards can best be left to the industry, academia could play a relevant role by simulating how the logistics industry and its performance would look if the industry would succeed in developing and widely adopting standard network operation protocols, standard load carriers, non-branded vehicles, standards for data-sharing and electronic transfer of documents (E-CMR), Etc.

Profit sharing

Because of its importance for sustained collaboration and because of its rich multifaceted academic nature, profit and cost sharing is perhaps the most studied element of collaborative logistics in literature today. However, it is not yet totally clear how to efficiently compensate participants for entering collaborations. Most studies assume that the cost minimization and cost allocation can be seen independently from each other. It seems that the combination of these two problems is the most challenging, but also promising research directions in this field. For the sake of practical applicability and acceptance, researchers should go for an approximation method of game theoretical solutions that is able to combine the advantage of stability with efficient calculation. A final direction for further research regarding profit sharing is how first mover companies can be rewarded for take the risk of setting up a 4C initiative, compared to companies that join later and benefit from the same overall efficiency improvements.

Archetypical collaborations

The review of literature on horizontal collaboration in Chapters 5 and 6, resulted in a new extended typology that was summarized in Table 16 and Table 17. It captures more of the important characteristics of horizontal collaboration than any other typology proposed in literature. A potential drawback of such a rich typology is that theoretically a great number of possible combinations can be made. The 15 dimensions together with their possible values allow for more than 100 million possible ‘unique’ collaboration types. Of course, not all these combinations make sense. Therefore, following the approach taken by Schmoltzi and Wallenburg (2011), it is an interesting direction for further research do define archetypical collaboration types based on this new extended typology. These would be the most observed or the most promising collaboration types based on the 15 dimensions listed. As argued in Section 6.1, this can help to come up with set-ups that have not been tried in practice before. The archetypical collaboration types should have the current position and role of companies in mind as a starting point. Some companies might be able to strive for more advanced forms, some need practical tools that directly show results.

Industry effect

A final direction for further research is of an industrial economics nature. In Europe (via a series of Horizon2020 project calls) and in the Netherlands (via the 4C agenda) the concept of horizontal collaboration has been promoted quite strongly already. An often heard complaint is that LSPs may suffer from the rise of 4Cs as it takes away some of the added value that they wish to offer to their customers themselves, for example a good price proposal that is made possible by combining transport flows with the flows within the client group of this LSP. This arguably is a step towards commoditization of the traditional transport industry. How big this impact is, is still open question to answer. Is it distorting the market? Or is it speeding up a beneficial development that was anyway going to happen soon? In other words: is a government funded program like 4C market structuring or market distorting?

11.3 For policy makers

From insights to results

After a decade of applied research on 4C, now is probably the time to redirect government support towards 4C start-ups with actual implementations. A good step in the light of this continued move from theory to practice is the shift of the Dutch TSL from stimulating a fixed list of topics among which is collaboration, to stimulating three main application areas instead. Tentatively, these application areas are: Corridors, Supply chains, and city logistics. This approach is better suited to provide the industry with the improvement projects it is asking for, even if these projects are less innovative or disruptive.

Stimulate or regulate

Over the last ten years the Dutch government, via TSL, has stimulated the creation, adoption and scaling of 4C initiatives at arm's length. In this manner, without direct intervention, TSL has placed horizontal collaboration firmly in the hearts and minds of logistics decision makers as a possibility to achieve efficiency improvements. Some important barriers are removed through academic research, and best practices of 4C projects (positive and negative) have been shared in the press, at round tables and through conferences. Despite this increased awareness however, 4Cs are not appearing very fast and once they are installed usually they have difficulty in scaling to a level that they do not need government funding anymore, let alone disrupt the traditional way of working in supply chains. Fortunately, the government still has several options that will more directly enforce efficiency improvements, rather than stimulate them. The most obvious measure would be to include the hidden costs in transport prices by means of a carbon tax. But other options are also available, such as restricting access to certain regions for vehicles that have a too low payload for this region. Whether or not to impose such regulation is a political choice, but it is expected that it will have a more immediate impact than the current arm's length stimulation strategy.

European rules can also become more and more consequential for the logistics industry. An example of successful European regulation is cabotage. One of the aims of horizontal collaboration in logistics is to contribute to reduce empty backhauls. In Europe empty backhauls represent about 25% of road transport activities (European Commission, 2011). Therefore, regulations exist to allow haulers to cross foreign countries during their return trip and pick up loads in countries where the vehicle is not registered. This practice, called cabotage, helps to optimize the use of capacity of the hauls. (Juan et al, 2014) and can strongly enhance an international 4C business case.

Also on a European level, SENSE (2020) advises to explore the re-design of all regulations that affect the execution of global freight transport network services (e.g. BER, Incoterms, Rotterdam rules, Maritime Single Window) in a way that they better facilitate collaboration. With any change in regulation, given the international playing field of transport, it will be important to create or maintain a level playing field for all transport companies in the EU.

Logistics clusters and corridors

The business case of horizontal collaboration through a 4C is more promising if there is a high synergy potential in the consortium of companies that are orchestrated by this 4C. This synergy can be increased if the logistics facilities of complementary companies are located close to each other, for example in a logistics cluster. It was noted by Van Breedam and Vannieuwenhuyse (2018) that logistics clusters form a good possibility to stimulate collaboration. These clusters can then be interconnected by so-called freight corridors, which is also a key element of the EU's Trans-European Transport Network (TEN-T) strategy. The TEN-T policy addresses the implementation and development of a European-wide network of railway lines, roads, inland waterways, maritime shipping routes, ports, airports and railroad terminals. The ultimate objective is to remove bottlenecks and technical barriers, as well as to strengthen social, economic and territorial cohesion in the EU[28]. Cruijssen (2019) discusses how the TEN-T network could be an early version of a physical internet that fosters collaboration through bundling and transshipment at major logistics nodes in Europe. Further stimulation of clusters and corridors is therefore recommended.

Focus on SMEs

Looking back at the birth of the 4C concept, it is striking that even in the definition by Van Laarhoven (2008) the focus is on big (international) shippers. As the program developed in the years 2010-2020, this emphasis shifted to include and later even focus on LSPs and SME shippers. This now seems logical, since SMEs have less scale than their multinational colleagues, and therefore usually have more to gain by

[28] Source: https://ec.europa.eu/transport/themes/infrastructure/ten-t_en

bundling flows with other companies. Most of the recent 4C pilot projects have focused on SMEs, and it is advised to maintain this focus.

Orchestration of opinions

Tavasszy (2015), in the light of the 4C4D project discussed in Section 8.4.2, noticed the idea of 'dominant perspectives'. In a typical innovative 4C project, many stakeholders are involved. And the more stakeholders there are in an innovation project, the more perspectives there will be on what the best approach and solution will be, and sometimes this leads to an unproductive chaos of opinions. To avoid this and to structure the development process of a 4C, it makes sense for a project coordinator to explicitly formulate a small number of dominant perspectives in the project. Van Breedam and Vannieuwenhuyse (2018) also state that the inefficiency of the transport industry is mainly due to the large number of stakeholders that all try to get the best possible result for their own interest. It is therefore important to bring these public and private stakeholders together on a single discussion platform to find dominant perspectives. In that way, we can avoid that 4C becomes a debating topic rather than a business strategy. With the current synthesis study hopefully some new dominant perspectives have been added.

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