Chapter 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 Fig. 5.1. Incidentally or not, the steep rise in published papers per year coincided with the launch of the 4C program in the Netherlands in 2010.

The growing attention for collaborative logistics in academia is further illustrated by the fact that roughly every 5 years a new literature review appears, see Table 5.1. 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. (2007c) 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).

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, (6) Legal and Regulatory

F. Cruijssen, *Cross-Chain Collaboration in Logistics*, International Series in Operations Research & Management Science 297,
https://doi.org/10.1007/978-3-030-57093-4_5

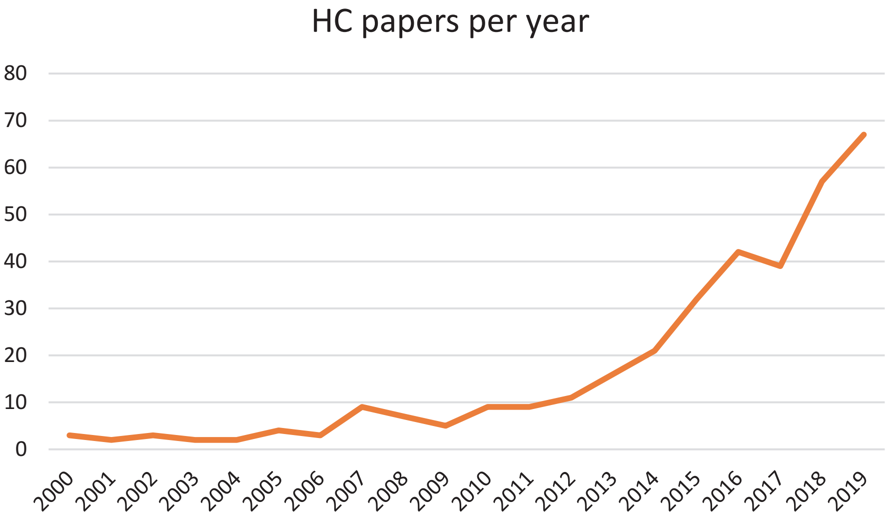

Fig. 5.1 Peer-reviewed papers on horizontal collaboration in the period 2000–2019

Table 5.1 Literature reviews on horizontal collaboration in transport and logistics

Year	References
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. (2007c). 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., & Hartl, R. F. (2018). Collaborative vehicle routing: A survey. *European Journal of Operational Research*, *268*: 1–12
2019	Pan, S., Trentesaux, D., Ballot, E., & Huang, G. (2019). Horizontal collaborative transport: Survey of solutions and practical implementation. *International Journal of Production Research*, *57*: 5340–5361

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 Chap. 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 5.2.

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 an 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

Table 5.2 Horizontal Collaboration (HC) terms found in literature

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 Sect. 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 (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 Sect. 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 5.3 Research topics categorized by Gansterer and Hartl (2018)

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

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 5.3.

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.

Table 5.4 Comparison of different collaboration types (Huijink 2016)

	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

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 (Table 5.4).

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 manifest itself at interpersonal, 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 inter-organizational 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) lists 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 5.5.

The concept of the independent arbitrator (later called a “trustee”) mentioned in Table 5.5 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

Table 5.5 Actors in horizontal shipper collaboration projects (TNO 2005)

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 Chap. 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

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 start-up 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 5.6. 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.

Table 5.6 Offline and online functions of a trustee

Online functions	Explanation
Loads combination	A trustee should be able to fully support a company 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)

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 vehi-

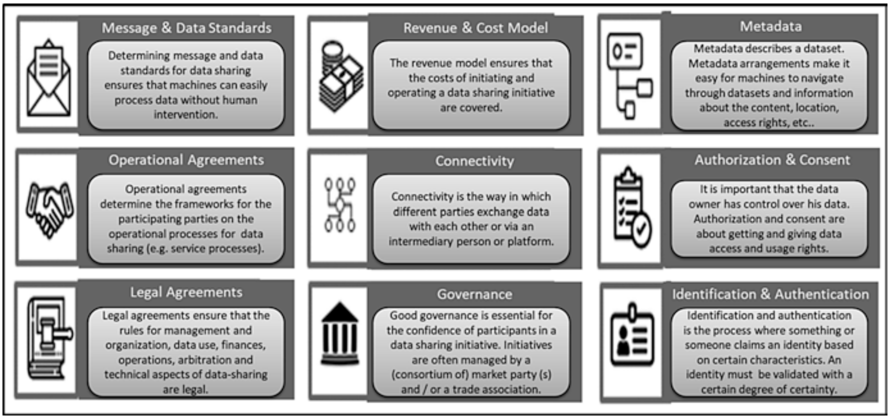

Fig. 5.2 Essential building blocks as basis for responsible data sharing

cle 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.

TNO (2020b) discusses the complexity of data sharing in logistics. They list nine building blocks that are key for data sharing in supply chains (see Fig. 5.2) and stress that a future-proof data infrastructure for logistics should be developed. Such an open environment will facilitate safe, efficient, and automated data sharing to organize and execute logistics processes in a sustainable, efficient, reliable, and flexible way.

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 Sect. 7.3) 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[1] 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. 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 5.3 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.

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

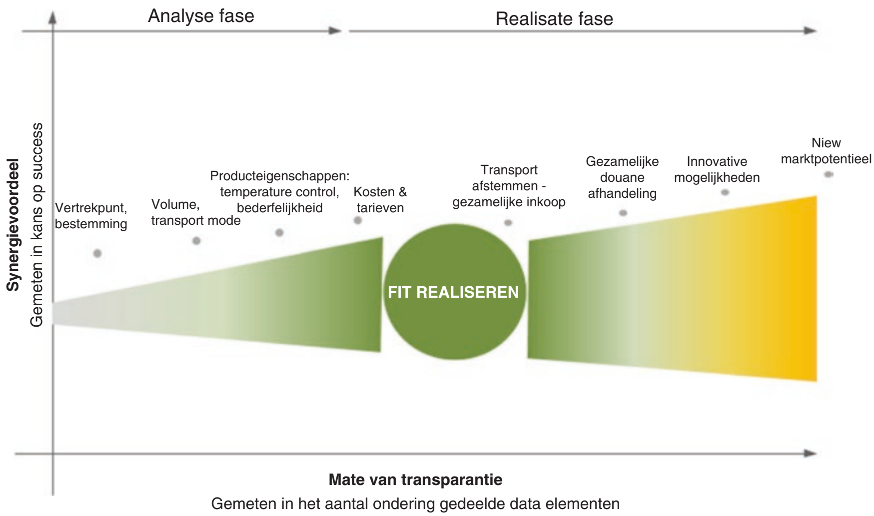

Fig. 5.3 Data richness and synergy assessment (In Dutch)

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. Therefore, 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 5.7 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.

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

Table 5.7 Properties of gain sharing mechanisms

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

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 et al. (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 (Table 5.8).

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

Table 5.8 Contracts used in horizontal collaboration projects

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

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 trade-off 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 5.9.

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 affect 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.

Table 5.9 Rules of thumb for competition law obeyance under horizontal collaboration

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

- 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) improves 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%.[2] Although there is not yet much formal regulation or jurisprudence on the topic of horizontal collaboration in supply chains, legal experts believe that there is ample room for horizontal collaboration if it can be substantiated that it leads to societal benefits.[3]

[2] How this "market" is defined and restricted is an important question still.

[3] See https://www.sva.nl/syllabus/juridische-grenzen-aan-horizontale-samenwerking (In Dutch)

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 Sect. 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 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.