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A synchromodal maturity model illustrated

Pressure on more sustainable transport and increased congestion provide opportunities for intermodal transport, but it suffers from unreliable transport times due to a lack of coordination at the operational level.

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Abstract

Pressure on more sustainable transport and increased congestion provide opportunities for intermodal transport, but it suffers from unreliable transport times due to a lack of coordination at the operational level. Synchromodal transport can mitigate this effect by taking an integral perspective. It appears that the majority of research to date has focused on the technical and operational challenges of synchromodal transport such as planning and supporting IT systems and platforms. In this article, a synchromodal maturity model has been applied to 41 cases to gauge the current state of synchromodal transport from a complete perspective.

Introduction

Transport volumes have increased steadily over the years and pressure continuously increased to make it more efficient and effective. Road transport has seen increased levels of congestion, resulting in unreliable travel times, and at the same time prices are expected to increase due to increased oil prices, and road tolls. Moreover, road transport will become subject to legislation aimed at reducing greenhouse gas emissions (European Commission, 2011). Road transport is with 75.3% currently still the dominant mode of transport of inland freight transport (18.7% for rail, and 6.0% for inland waterways), and the total volumes have increased in the EU by 10.5% between 2013 and 2018 (Eurostat, 2021). These combined trends have ensured that alternatives should be sought in several directions to reduce emissions from (inland) transport and simultaneously meet the increasing demand.

In the last 15 years, the amount of vessels with a capacity of over 8,000 TEU has increased from a mere percent to an expected 56% in 2022, with 15% and 16% for over 12,000 TEU and over 15,000 TEU vessels as part of the global fleet (Sánchez, Perrotti, & Fort, 2021). This trend reduces the transport cost per container for the intercontinental leg. However, it also results in more congestion at the ports due to large numbers of containers being released in a short amount of time, especially for unloading, customs checks, and transport preparation.

Road transport was traditionally a more attractive mode of transport due to shorter lead times, and therefore lower pipeline inventory. Due to growing congestion and increasing costs, intermodal transport is becoming a better alternative compared to road transport. However, current frequent delays in intermodal transport need to be resolved to make it a good alternative to road transport. It has been observed that the full potential of multimodal transport is not yet exploited due to a lack of coordination at the operational level, which leads to inefficiencies in the hinterland intermodal transport system (Gumuskaya, van Jaarsveld, Dijkman, Grefen, & Veenstra, 2020).

Exactly these disadvantages can be overcome when focusing on synchronizing intermodal transport by taking an integral perspective: synchromodal transport. Several definitions exist of synchromodality. Here the definition of Van Riessen, Negenborn, and Dekker (2015) is employed: "synchromodal transport is intermodal planning with the possibility of real-time switching between the modes or online intermodal planning". Synchromodal transport extends intermodal transport with real-time changes and flexibility. Real-time planning can be executed when real-time information from several partners in a supply chain is combined into one system, which requires a good relationship between these different partners.

Real-time insight into the state of the network allows for optimizing rail and barge capacity to reduce cost per shipped container and emissions. Moreover, it allows for more reliable transport times by deviating to a different modality in case of disruptions. As a result, improved reliability, better prices, and/or reduced transport times are realised for shippers, compared to intermodal transport.

Despite the benefits, synchromodality is not yet executed on a large scale in practice, and most of them are set up in the Netherlands. A few representative companies are mentioned here. European Gateway Services (EGS) offers a variety of intermodal and synchromodal transport services since 2009, connecting the ports of Antwerp and Rotterdam to the main economic regions in West and Central Europe (EGS, 2021). In total, they transport yearly around 1M TEUs by connecting the ports to 12 inland terminals and operating 30 weekly inland barge services and 40 weekly rail services. TEUBooker (TEUBooker, 2021) currently has a position as an independent synchromodal transport platform in Rotterdam and sufficiently regular customers are committed to expanding to Dutch inland terminals and even longer corridors such as Germany/UK shortly. Combi Terminal Twente (CTT, 2021) is a synchromodal logistics service provider with multimodal terminals in Hengelo, Almelo (both inland shipping), and Rotterdam (inland shipping and rail). CTT provides frequent inland shipping services between the ports of Rotterdam and Twente, from where containers are moved further into the hinterland. Conversely, container flows from shippers are transported in the Twente region to Rotterdam. With its rail terminal in Rotterdam (Pernis), CTT is also able to offer rail services to its customers, for example towards Poland. The reasons for limited implementations are that some difficult issues have to be resolved beforehand, especially in the area of horizontal collaboration and willingness to share data (Alons-Hoen & Vannieuwenhuyse, 2021).

The contribution of this article is as follows. Firstly, to reveal the research gaps in the current literature by investigating the practice of synchromodality using the synchromodal maturity model of Alons-Hoen and Somers (2017) in Section 2. Secondly, an illustration of the usage of the synchromodal maturity model is shown in practice and the main barriers to synchromodality are identified. In Section 3, the methodology of Alons-Hoen, van Duin, and Somers (2019) is further standardized for a more accurate determination of the level of synchromodality and allows for comparison between roles. The results and discussion are presented in Section 4 based on the 41 structured interviews. In Section 5 conclusions are drawn and future research for synchromodal transport is derived.

Literature review on synchromodality

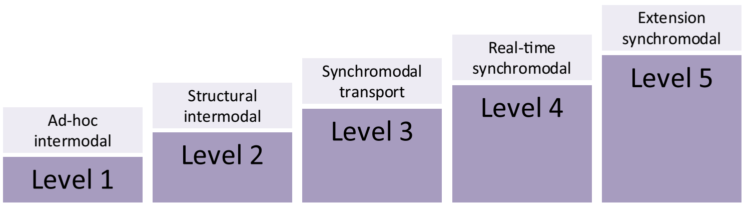
This section starts with a short introduction to the development of synchromodal transport. Next, the synchromodal maturity model is explained and the existing literature is mapped to it. This literature review is not intended to cover the full scope of relevant articles however just to highlight which parts have been covered so far.

The concept of synchromodal transport originated in the Netherlands in the early 2000s (Fransoo, 2011; Verweij, 2011), and has been one of the focus areas of Topsector Logistiek, a high-potential area defined by the Dutch government, since 2012 (Platform Synchromodaliteit, 2021). As a result, the first scientific articles also originated from the Netherlands, including (Behdani, Fan, Wiegmans, & Zuidwijk, 2016; Tavasszy, Behdani, & Konings, 2018; van Riessen, Negenborn, Lodewijks, & Dekker, 2015). It is now also being investigated in other geographic regions: in Austria (Pfoser, Treiblmaier, & Schauer, 2016; Prandtstetter et al., 2016), Greece (Kapetanis, Psaraftis, & Spyrou, 2016), Ghana (Agbo, Li, Atombo, Lodewijks, & Zheng, 2017), Turkey (Resat & Turkay, 2019), and Lithuania (Batarlienė & Šakalys, 2021).

Several studies have been performed to identify critical success factors for synchromodal transport by investigating the acceptance and implementation of synchromodal transport. The first article that investigates critical success factors of synchromodal transport is the article of Pfoser et al. (2016). They conclude that sophisticated planning and ICT/ITS technologies as viable enablers and Network, Awareness, Legal, and Pricing as critical enablers. These critical enablers are important but hard to realize. Another study (van Duin, Warfemius, Verschoor, de Leeuw, & Alons-Hoen, 2019) investigated the success and failure factors of synchromodal transport of Pfoser et al. (2016) applied to a case study in the Port of Rotterdam. Their main conclusion was that different barriers were perceived by experienced and non-experienced users, where pricing, awareness, and network are the main barriers for non-experienced users. For experienced users, the main barriers are infrastructure, legal framework, sophisticated planning, and cooperation.

This provides guidance on which factors are necessary for a successful implementation. Giusti, Manerba, Bruno, and Tadei (2019) also investigated the critical success factors of Pfoser et al. (2016) and they concluded that the ICT/ITS technologies are the meta-critical success factor, thereby enabling all other factors.

Synchromodal transport lacks a uniformly accepted definition and different researchers emphasize different aspects (Reis, 2015; Singh, van Sinderen, & Wieringa, 2016). Implementing synchromodal transport impacts the following stakeholders: terminals, logistics service providers (third-party and fourth-party) customers (or shippers), and carriers (Giusti et al., 2019). Synchromodal transport is perceived in most articles as something a company engages in or not. Alons-Hoen and Somers (2017) describe a staged approach where companies mature their (transport) processes in five stages towards synchromodal transport: the synchromodal maturity model. The maturity model enables companies to identify the maturity of their current way of working and allows for the identification of areas to improve the synchromodality of their transport process.



	Level 1	Level 2	Level 3	Level 4	Level 5
Execution of transport	Truck => 80%	**Train or barge => 40%**	Train or barge => 60%	Train or barge => 80%	Train or barge =100%
Transport planning	Ad-hoc, no forecast	0-40% planned based on forecast	41-100% planned based on forecast	**Real time orders in supply chain**	**Real time orders and stock levels**
Data exchange	Per container	Forecast per customer	Forecast per customer	**Control tower to share data with more parties**	Control tower + real time stock levels
Key performance indicators	Price and time	Price and time per modality	Price, time, reliability	Price, time, reliability and utilization degree	Price, time, reliability, utilization degree and service level
Decision making power	Shipper 81-100% of orders	More than 20% a-modal booking by other party	**Orders shared in supply chain**	Real time orders in supply chain	Real time stock level in supply chain
Type of relationship	Transactional	**Limited vertical**	Intensive vertical, limited horizontal	Intensive vertical and horizontal	**Intensive vertical and horizontal + real time stock levels**
Pricing	Spot market	Alignment on tariff (tender)	**Tariff per modality and a-modal booking**	**A-modal booking and a modal pricing**	A-modal booking, a modal pricing and real time stock levels

Figure 1 Synchromodal maturity model (Alons-Hoen, van Duin, & Somers, 2019)

Alons-Hoen and Somers (2017) define seven key process areas that, together, characterize synchromodal transport: Transport execution: how transport is executed.

- Transport planning: how transport is planned (planning horizon).
- Data exchange: the data requirements of the selected transport planning.
- Key performance indicators: parameters that are tracked to monitor the performance of the transport process.
- Decision-making power: stakeholder decisions on how and when the transport is executed.
- Type of relationship: the extent of vertical and horizontal collaboration between companies.
- Pricing: how the pricing process is executed (tariff setting and payment).

Figure 1 summarizes the synchromodal maturity model and indicates the major changes when transitioning from one level to another. A more detailed description of the model that includes the changes per role level is given by Alons-Hoen, Somers, and van Duin (2019).

The synchromodal maturity model allows for the categorization of the available literature on synchromodal transport. Table 1 presents an overview of the most relevant articles on synchromodal transport, categorized by their topic.

Table 1 Synchromodal research by process area

Key process area	Publications
Execution of transport	Pfoser et al. (2018)
Transport planning	• Van Riessen, Negenborn, and Dekker (2015), van Riessen, Negenborn, Lodewijks, et al. (2015) • van Riessen, Negenborn, and Dekker (2016), Zhang and Pel (2016), Behdani et al. (2016), Mes and Iacob (2016) • Dong, Boute, McKinnon, and Verelst (2018) • Ambra, Caris, and Macharis (2019), Lemmens, Gijsbrechts, and Boute (2019), Pérez Rivera and Mes (2019), Qu, Rezaei, Maknoon, and Tavasszy (2019), Resat and Turkay (2019) • Guo, Atasoy, van Blokland, and Negenborn (2020) • Batarlienė and Šakalys (2021), Yee, Gijsbrechts, and Boute (2021)
Data exchange	Singh and van Sinderen (2015) Giusti, Manerba, et al. (2019), Giusti, Iorfida, et al. (2019)
Key performance indicators	Tavasszy et al. (2018)
Decision-making power	Khakdaman, Rezaei, and Tavasszy (2020)
Type of relationship	Chen et al. (2017), Basso, D'Amours, Rönnqvist, and Weintraub (2019), Plasch, Pfoser, Gerschberger, Gattringer, and Schauer (2021)
Pricing	van Riessen, Negenborn, and Dekker (2017), Van Riessen, Mulder, Negenborn, and Dekker (2020)

It is clear from this table that the majority of the articles focus on all aspects of transport planning (from strategic to tactical to operational planning decisions in synchromodal networks). Some literature is available on data exchange and the required ICT/ITS technology. Van Riessen studied the synchromodal pricing problem: van Riessen et al. (2017) and Van Riessen et al. (2020). Pfoser et al. (2018) investigate the impact of high-performance transport modes, such as hyperloop, in synchromodal networks and conclude that it provides mutual benefits (Tavasszy, Behdani, & Konings, 2018) define that a synchromodal service has five key performance indicators: reliability, cost, speed, sustainability, and flexibility.

The relationship type covers both the vertical collaboration between shippers, logistics service providers, and operators, as well as horizontal collaboration between logistics service providers, or any of the other parties. The topic of supply chain collaboration, in general, is a well-studied topic, see Chen et al. (2017) for a literature review on supply chain collaboration to increase sustainability. Basso et al. (2019) highlight potential practical issues that explain why implementations of horizontal collaboration are scarce despite the potential benefits. Plasch et al. (2021) study reasons for collaboration and success factors for the Physical Internet setting, which they perceive as an extension of synchromodal transport. They observe that companies engage in a physical internet network for a competitive advantage, access to network resources, or efficient processes. According to them, the necessary success factors are a central orchestrator platform and the alignment of resources.

Methods

A questionnaire was used in this research to determine for each of the companies the maturity level per key process area. In Section 3.1 the setup of the questionnaire is described. Then, Section 3.2 describes how the answers were converted into a score for each process area of the maturity model, and finally, Section 3.3 describes the way of working to collect the data.

Questionnaire structure

The goal of this research is to investigate the maturity of synchromodality in practice. A questionnaire was used to determine the maturity level of companies because it allows for statistical comparisons and analyses. The characteristics of a questionnaire fit best with the features of a maturity model. The questionnaire of Alons-Hoen, van Duin, et al. (2019), with more open-ended questions, was used as a starting point for this research. A calibration session with the research team resulted in more closed questions that allow for straightforward calculation of the score for each of the areas of the maturity model.

In Table 2 the number of questions and the subjects per key process area are summarized. In total 12 questions were asked related to the key process area and seven questions were asked related to the company in general. Three of these questions are closed questions related to the role of the company in the supply chain, the volume, and the type of containers used. The other four questions are open questions about the company name, location, number of employees, and the transport corridors used. The questionnaire can be obtained from the authors upon request.

Table 2 Questions per key process area

Key Process Area	No. of questions	Topics
Transport execution	2	Modality, share of modality
Transport planning	3	Forecast, communication
Data exchange	4	Forecast, communication, # parties for data exchange
KPIs	2	Performance measurement, KPIs

Method of analysis

This section describes how for each key process area the answers to the related questions are combined into a single score per process area. The maturity level for the key process area *Transport Execution* is defined based on the usage of Intermodal (rail/barge) transport. In the first question, the usage of the three modalities is ranked. In the second question, the share of the total volume transported by each modality is indicated. See Figure 6 and Figure 7 in the appendix. For instance, if one company has ranked the modality Barge as the number 1 modality and the volume of Barge and Rail together is higher than 60%, then the maturity score for "Transport Execution" is at level 3. Technical reasons prohibited the authors to determine this in single questions.

Some of the key process areas are more complicated to determine, e.g., *Data exchange*. The score of four questions is combined to determine the level of the key process area. These multiple-choice questions have 2 to 6 different answers, indicated by the number in front of the question. The questions are:

- [2] Is a forecast shared with another party in your supply chain? (Either by you or another company)
- [3] Which percentage of the total needed capacity is planned based on forecasting of your supply chain partner(s)?
- [4] With how many parties are data exchanged to organize your transport?
- [5] Which mode of communication is mainly used for sharing orders or stock levels?

Each of the answers is awarded a number of points and the total score determines the score for the maturity level of *Data exchange*. Some of the questions are used for determining the level of more than one key process area. Table 8 in the Appendix maps the questions to the key process areas.

Data collection procedure

An online structured questionnaire is used to collect the answers. All answers are stored in the project database for analysis (benchmarking) on regions, branches, or company types. Based on the answers of the company, an algorithm converts it to the level of maturity for all seven key process areas and automatically generates a textual report to explain why a certain company is at a given maturity level for a particular key process area. The answers and maturity levels are input for the maturity level report that is provided to the company. In Figure 2 an example of the text from the automatically generated maturity level report is shown.

Data exchange Level 3
For Data exchange you are currently at Level 3, because 61 – 80% of your capacity is reserved bases on a shared forecast. To organise your transports you share data with 2 – 3 parties. Additionally, regular orders are communicated via EDI and real time orders using EDI.

Figure 2 Text Data exchange report

The report describes the current state of intermodal and synchromodal transport of a company, including a benchmark with similar companies in the database. Moreover, advice is given on how the company can improve to a higher level of synchromodality. An example of the benchmark figure can be seen in Figure 3.

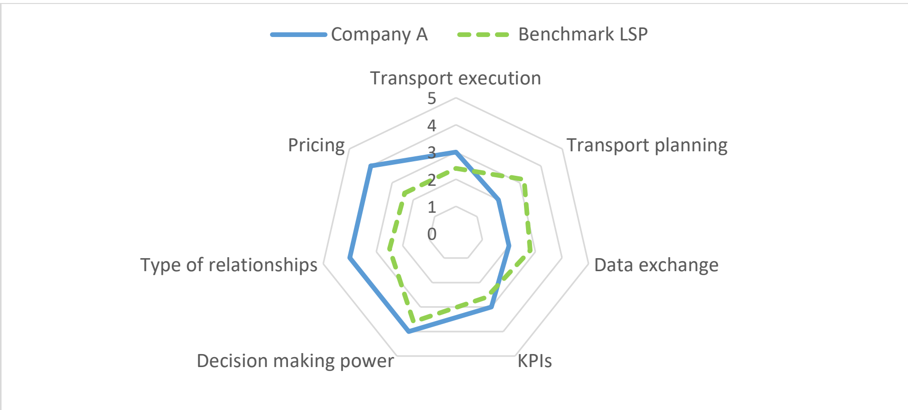


Figure 3 Example of a company benchmark

The interviews were held by students in the field of Logistics and Business administration and they were also responsible for entering the answers into the online questionnaire. The application of the maturity model is integrated into the study programs of the Universities of Applied Sciences and students receive credits for the application of this model. The data collection procedure is visualized in Figure 4. Workshops are provided to students on how to apply the Maturity model, including fictional cases. The goal of these workshops is threefold: intermodal and synchromodal transport is explained to the students, they learn to understand the maturity model, and finally how to work with the online questionnaire concerning the maturity model.

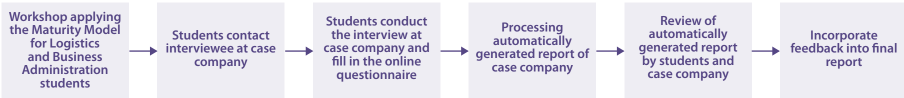


Figure 4 Data collection procedure

Students arranged the interviews with the companies and conducted them in groups. After the students fill in the online questionnaire using the responses of the company, students receive an automatically processed report from the research consortium, based on the given answers by the company. Based on this general report, students plan a new appointment with the company to specify the advice for the specific situation and strategy of the company.

Data sample

Students are instructed which companies to approach and how to interview them using the online questionnaire. They selected companies that are already familiar with intermodal transport in their region and it was required that the interviewee worked in the transport planning department. Throughout 2019 and 2020, 41 companies have been interviewed.

Table 3 Classification of TEU turnover per role (# of companies)

	NA	0-500	500-1500	1500-3000	3000-6000	> 6000	Total
Logistics service provider	2	1	1	6	3	10	23
Forwarder	0	0	1	0	0	0	1
Hinterland operator	0	0	0	0	0	1	1
Shipper or manufacturer	2	2	1	3	2	5	15
Shipping line	0	0	0	0	0	1	1
No. of companies	4	3	3	9	5	17	41

Table 3 shows the respondents classified on their role in the supply chain and the annual TEU turnover. The four respondents listed as 'NA' transport goods in bulk, rather than in containers. The majority of the companies (10) are logistics service providers (LSPs) involved with shipping over 6,000 TEU annually. The distribution over the different roles is not representative of the overall population as some roles are underrepresented: no response was obtained for terminal operators. Care has therefore to be taken when interpreting the results and the detailed analysis per role (Section 4.2) is executed for LSPs and shippers only. The number of containers that are shipped by the LSPs and shippers/manufacturers shows a similar distribution.

Results and discussion

In this section, the findings from the 41 interviews are presented and interpreted. In Section 4.1 the synchromodal maturity scores of the entire sample are described. Next, the results for shippers and LSPs are compared in Section 4.2.

Overall synchromodal maturity scores

The key process area scores are summarized in Table 4. It can be seen how the 41 responses are divided over the 5 levels for each key process area. The table also shows the average and standard deviation of the levels per process area. Transport execution is lagging since 15 companies have a level 1 score. It can be observed that the scores on transport planning are relatively extreme: the majority has a level 5 score and the second largest group has a level 1 score. Data exchange has an opposite distribution: almost no level 1 and 5 scores and relatively evenly spread among levels 2, 3, and 4. Using inventory levels for transport planning seems to be occurring already. However, the data exchange seems to lag and suggests that it can be done without state-of-the-art information technology.

Table 4 Spread of maturity level scores per key process area and average (# of companies)

Key process area	1	2	3	4	5	Average score	Predicting score
Transport execution	15	9	10	2	5	2.34 (1.34)	0.34
Transport planning	10	2	3	7	19	3.56 (2.05)	0.29
Data exchange	1	16	12	12	0	2.85 (1.01)	0.44
KPIs	11	5	8	9	8	2.95 (1.60)	0.34
Decision-making power	10	1	15	3	12	3.15 (1.69)	0.39
Relationship type	11	4	20	4	2	2.56 (1.15)	0.54
Pricing	7	15	12	5	2	2.51 (1.08)	0.46

The results show that there are some companies already relatively advanced in transport planning, exchanging the relevant data, and decision-making power. In contrast, the execution of intermodal transport, the relationship type, and the pricing process seem to be lagging. These results are in line with Basso et al. (2019) who conclude that trust, autonomy, and sharing of sensitive information are hurdles that limit horizontal cooperation in logistics. Synchromodal platforms are available in practice, but is it the real enabler of synchromodal transport, as hypothesized by Giusti, Manerba, et al. (2019)? Or, are the hurdles for horizontal cooperation preventing companies from considering synchromodal platforms, as suggested by (Alons-Hoen & Vannieuwenhuyse, 2021)? This is another, and critical, research topic to investigate further.

Regarding pricing, it can be concluded that it is lagging behind most other factors. A-modal pricing is executed to some extent but then corrected afterwards for actually used modalities. The usage of a true a-modal (or integral) price per lane is only implemented on a very limited scale. This could provide evidence that a true synchromodal mind-set is not present yet, as concluded by Alons-Hoen and Vannieuwenhuyse (2021), or that the level of trust is not yet sufficient to accept this pricing scheme. Hendrickx (2020) suggests that a synchromodal platform and intensive horizontal cooperation are necessary preconditions for a-modal pricing (or synchromodal products). Also, the positioning of synchromodal products next to traditional intermodal products could play a role. Van Riessen et al. (2020) derive two synchromodal products (regular and express) for a case study in the network of EGS. It would be interesting to extend this research to identify what the offering should be for different kinds of customers: shippers and forwarders and under what conditions is it acceptable. It is especially interesting to extend this research in the other direction toward operators and shipping lines. What pricing scheme, or cost allocation scheme is required to provide a successful collaboration? Since Basso et al. (2019) indicate that cost allocation is one of the barriers to successful horizontal collaboration. The majority of the literature to date focuses on LSPs, sometimes including shippers (Dong et al., 2018). Investigating the role and the incentives of operators is essential to get them on board to fully embrace synchromodal transport.

To understand which component of the maturity model is most important for the overall maturity of the company, the median score of the 7 components was derived for each company. This median score is labelled the overall score and is displayed in Table 5.

Table 5 Median synchromodal score per company type

Overall score	1	2	3	4	5	No. of companies
Logistics service provider	4	5	11	2	1	23
Forwarder	1	0	0	0	0	1
Hinterland operator	0	0	1	0	0	1
Shipper or manufacturer	0	2	11	2	0	15
Shipping line	0	1	0	0	0	1
No. of companies	5	8	23	4	1	41

For each key process area, the score can be compared to the overall score for all companies. The number of matches then determined the predicting score of that key process area and can be observed in Table 4. The highest score is obtained for relationship type (0.54): for 22 companies the relationship type score reflects the overall score of the company and for 7 the factor score exceeds the overall score. For companies, the appropriate relationship type seems a requirement to obtain a certain level of synchromodality, but it can of course also be applied to a pure road transport setting to optimize capacity utilization and efficiency.

Table 6 Average scores key process areas per overall score

Overall score	1	2	3	4	5
Transport execution	1,20	2,50	2,48	2,75	2,00
Transport planning	1,00	3,25	3,96	4,75	5,00
Data exchange	2,00	2,63	2,91	3,75	4,00
KPIs	1,80	2,13	3,30	3,50	5,00
Decision-making power	2,20	3,38	3,00	4,25	5,00
Relationship type	1,60	1,50	2,91	3,25	5,00
Pricing	2,20	1,63	2,65	4,00	2,00
No. of companies	5	8	23	4	1

In Table 6 the average score per key process area is shown for all companies with the same overall score. More than two-thirds of the population has a maturity score of at least 3, which implies that for at least 4 key process areas the synchromodal criteria are met. In Figure 5 the average scores of the key process areas per overall score are displayed graphically. For the level of transport planning, appropriate data exchange, and necessary KPIs it is observed that the key process area increase with higher levels of synchromodal transport (a higher overall score).

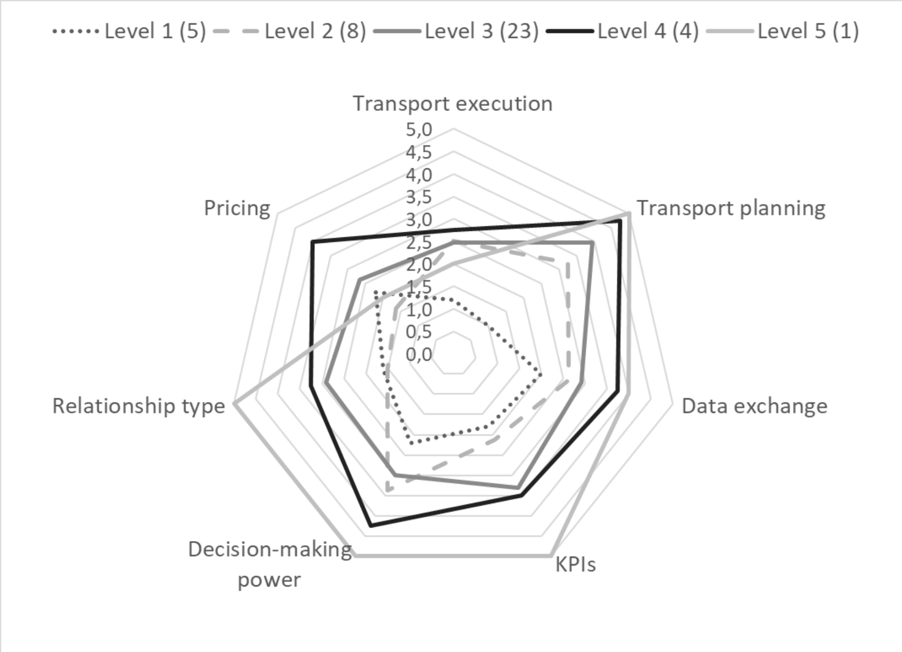


Figure 5 Average key process area scores

For decision-making power scores of level 2 exceed those of level 3, this is because a shipping line and a shipper both with level 5 decision-making power are included in level 2. For transport execution, the results are as expected, except for level 5, which represents the results of a single company. This is an indication that again the level of transport execution lags the other levels, as can be concluded for pricing at level 5. For pricing, the results are mixed and the higher score on level 1 can be explained by two logistics service providers with scores 3 and 4, which represent a-modal booking, with and without a-modal pricing, respectively.

Overall, the results seem to confirm that higher overall scores are linked to higher scores in each of the seven areas with a few exceptions, most notably for pricing, and to a lesser extent, for decision-making power. But the results are mainly caused by a few exceptional values. The largest increase can be observed for transport planning between the groups with levels 1 and 2. As soon as intermodal transport is performed structurally, the maturity of transport planning increase from 1 to 3. The sample contains relatively few companies with an overall score of level 4, or 5. This, on the one hand, seems to reflect reality, but on the other hand, requires caution when interpreting the results of these groups.

It would be worthwhile to investigate in detail how these companies progressed in terms of maturity to derive success factors that correspond with a full implementation of synchromodal transport.

Synchromodal scores per role

Next, the results between shippers and LSPs are compared by considering the average score per key process area. The analysis was only performed for logistics service providers (23) and shippers (15) due to the limited number of observations for the other roles. The average score per role and the standard deviation (between the brackets) are shown in Table 7.

Table 7 Average maturity scores per process area (and standard deviation)

Key process area	Logistics service provider (23)		Shipper or Manufacturer (15)	
Transport execution	2.26	(1.63)	2.47	(0.99)
Transport planning	3.35	(1.87)	3.87	(1.25)
Data exchange	2.70	(0.97)	3.07	(0.70)
KPIs	2.43	(1.38)	3.67	(1.50)
Decision-making power	3.65	(1.30)	2.40	(1.50)
Relationship type	2.43	(1.34)	2.87	(0.74)
Pricing	2.43	(1.12)	2.87	(0.92)
Overall	2.75	-	3.03	-

Overall, shippers have a higher average score than logistics service providers. This is also reflected in the median scores: 39% of LSPs have a score less than 3 and only 13% of shippers. Both 13% of LSPs and shippers have a score of 4, or higher. The higher scores are mainly obtained for transport planning, data exchange, and KPIs. The variation in transport planning level is relatively lower for shippers/manufacturers, suggesting that the majority is operating at the higher levels. The scores for relationship type and pricing are also relatively high. This suggests that the shippers in general have a good relationship with their logistics service provider, providing them the required data and agreeing on pricing. Moreover, the horizontal collaboration between parties is critical to the success of synchromodality (Pfoser et al., 2016), and it was observed in this study that it needs to improve shortly to take synchromodal transport to the next level.

Reliability is added at level 3 of the factor KPI, which seems to be very important to companies to monitor significant transport delays. One could expect that the scores for decision-making power and pricing are more aligned since level 3 involves a-modal booking and a-modal pricing. However, this is not observed in the data. It is striking that for LSPs transport execution has the lowest average score but the second highest score on variation. This suggests that there are a few exceptions that are ahead. For shippers, the same holds for decision-making power.

The least difference is observed for both roles on the data exchange part. Suggesting that the results are relatively equal across the sample. When comparing KPIs and decision-making power one sees opposing effects for LSPs and Shippers: where LSPs operate at a higher level of decision-making power the value of the reliability (added at KPI level 3) is relatively low, and the reverse is true for shippers. A high level of decision-making power facilitates the business of the LSPs and is, therefore, to be expected. This result provides some validity for the maturity model, as companies obtain higher scores on factors that they value and align with their role in the supply chain. The results from the questionnaire imply that some companies are moving towards synchromodal transport. However, road transport is still the predominant mode for LSPs in terms of modal split realized.

The maturity model was also applied by Alons-Hoen, van Duin and Somers (2019) to a case study in Belgium and the Netherlands. They observed a strong vertical collaboration between logistics service providers and shippers was observed, as was a-modal booking. Horizontal collaboration was observed as a hurdle and hampered synchromodal transport, as did the corresponding data sharing. Trust issues seemed to be blocking these factors. The conclusions from this research seem to align, however, data sharing was less observed as a hurdle, and pricing was lagging. The conclusions that can be drawn from the data are in line with the conclusion of Alons-Hoen, van Duin and Somers (2019): Shippers are more mature in synchromodal transport but LSPs have a more mature level of decision-making power. Vertical collaboration seems to be strongly supported by a higher score of data exchange for shippers. It is not possible to directly compare the results of this study and those of Alons-Hoen, van Duin and Somers (2019), because different information was used to determine the levels. Overall much higher scores were observed in this study, still it cannot be concluded that companies have advanced towards more mature synchromodal transport.

Conclusions

In this article, the synchromodal maturity model has been used to classify available literature on the topic and to investigate the maturity of synchromodal transport in practice. From the literature review, it appears that the challenges of synchromodal transport planning and the supporting IT platforms and systems (data exchange) are well investigated. However, the topics of relationship, synchromodal pricing, and decision-making power remain relatively untouched. The results from our questionnaire suggest that especially pricing and type of relationship are lagging. Decision-making power and key performance indicators are also a bit behind, especially for shippers. The transition to a true integral price and limited horizontal collaboration is not yet being made. This is in line with the conclusions of Alons-Hoen and Vannieuwenhuyse (2021) that a lack of trust between parties is the main bottleneck for engaging in a horizontal collaboration as well as the focus on price. Giusti, Manerba, et al. (2019) suggest that enabling information technologies are a meta-critical success factor that acts as a catalyst in the transition towards synchromodal transport. Experience from practice suggests that the price-focus and lack of trust are true barriers to overcome before IT systems are considered. It would be an interesting avenue to pursue how trust between parties can be enhanced, and how policymakers can contribute. Serious gaming, like for example You've Got Freight, is potentially a good option for companies new to synchromodal transport to create awareness as suggested by Kurapati et al. (2017).

In the current study, few observations were collected for shipping lines, hinterland operators, and terminal operators. A follow-up study that particularly investigates the usage of synchromodal transport by the suppliers of the transport capacity is required to get a complete image of the state of synchromodal transport. Our database includes the results of several studies. Based on these outcomes, only limited benchmark analyses can be made for some company types. A follow-up study will enrich the benchmark, and allow for a more complete view of the current state of intermodal transport.

Declaration

Availability of data and material

The data that support the findings of this study are available from the authors. Restrictions apply to the availability of these data, which were used under license for this study. Anonymous data are available from the authors with permission upon request.

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Appendix


14. How do the different modalities rank for your company based on volume transported? *

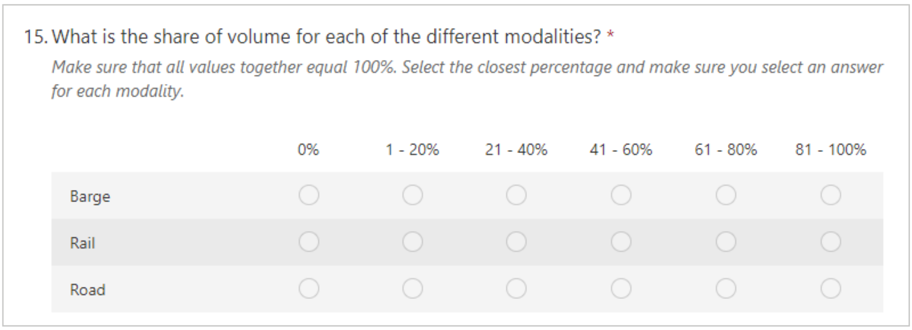
Where 1 is used most often and 3 least often

Barge

Rail

Road

Figure 6 Ranking transport modalities


15. What is the share of volume for each of the different modalities? *

Make sure that all values together equal 100%. Select the closest percentage and make sure you select an answer for each modality.

	0%	1 - 20%	21 - 40%	41 - 60%	61 - 80%	81 - 100%
Barge	○	○	○	○	○	○
Rail	○	○	○	○	○	○
Road	○	○	○	○	○	○

Figure 7 Share of volume per modality

Table 8 Questions per key process area

	Transport Execution	Transport Planning	Data Exchange	Key Performance Indicators	Decision-making Power	Type of Relationships
Rank modalities barge, rail, road	1					
Barge, Rail, Road %	1					
Forecast shared in the chain		1	1			
Share capacity planned on forecast		1	1			
# data exchange parties			1			
Orders, Real-time updated orders, Real time updated stock levels		1	1		1	
Transport KPIs				1		
Measurement KPIs				1		
A-modal shipping party					1	
Supply chain partner collaboration level						1
Pricing Agreements						
Price setting factors						
Level decision-making power						1
	2	3	4	2	2	2