

## Article

# Real-Life Sychromodality Challenges: A Qualitative Study in Flanders

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**Abstract:** The search for more sustainable freight transport has been the focus in the last decades. In this way, the concept of sychromodality was built considering the collaboration of shippers and logistic service providers to enable real-time switching between transport modes and mode-free transport bookings, encouraging more flexible and sustainable freight transportation. However, there are several challenges to its implementation in real life, which is the focus of this paper. To achieve this, in addition to a literature study, a case study was conducted in Flanders, using a combination of qualitative methods, i.e., focus groups (FG) and expert interviews, aiming to bridge the gap between theory and practice. Challenges such as real-time decision making, limited infrastructure capacity, and the need for stakeholder collaboration were emphasized. Expert insights highlight the need for a forecast-based approach to facilitate mode shift decisions, particularly from roadway to inland waterway transport (IWT). The analysis underscores the potential benefits of the proposed sychromodal technology while acknowledging the requirements needed to make it real.

**Keywords:** sychromodality; transport sychromodal; transport multimodal; inland waterway; freight transportation; real-time decisions



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## 1. Introduction

The literature over recent decades has consistently emphasized the urgency of finding environmentally sustainable solutions for freight transportation, particularly in response to growing climate change and environmental challenges. Conventional road-based freight transport has become increasingly unsustainable due to factors such as traffic congestion and environmental issues.

In the dynamic scenario of logistics and transportation, the sychromodal concept has been considered innovative as a solution to make long-haul freight transport more sustainable. However, implementing sychromodality in real-life settings is a complex challenge due to key factors such as data integration and accessibility, regulatory rules, infrastructure adaptation, technological integration, and operational coordination, among others. The successful deployment of this concept requires careful consideration of these factors. Numerous studies have been conducted on the sychromodality concept and framework, but an investigation of “How can the concept of sychromodal transport be implemented in a real-life setting?” from a practice point of view is lacking.

Flanders, strategically positioned in Europe, known for its dense network of roadways, rail systems, and the second largest port on the continent, is an attractive landscape for the application of sychromodal transport. This technological concept, which considers the coordination of diverse modes of transport in real-time, has the potential to redefine the region’s logistics scenario. However, knowing all of the obstacles to its implementation, this paper proposes a qualitative study that was developed to delve into the challenges that must be addressed to implement the concept of sychromodality in Flanders.

To achieve these goals, the methodological approach combines the strengths of two complementary research methods: focus group (FG) discussions and interviews with

experts. The first phase brought together experts in FG discussions. The discussions provided rigorous debates and knowledge sharing, enriching the study with diverse perspectives. Posteriorly, interviews were conducted with key stakeholders. It was also a target to engage in the topic those directly involved in shaping policies, strategies, and operational decisions in this region. Section 2 explores the literature on the synchronomodality concept and its challenges. Section 3 presents the case study. Section 4 provides the research approach, and Section 5 presents the results. To conclude, the final section of this paper gives the conclusions.

## 2. Literature Review

Sustainability is a topic discussed worldwide focusing on actions to minimize climate change and global warming. Given this, the United Nations has proposed 17 Sustainable Development Goals (SDGs), which involve the implementation of strategies to combat climate change and its impacts, among other objectives. Adding to this, the European climate law stated that the European Union (EU) countries must reduce their greenhouse gas emissions by at least 55% by 2030 [1].

Road transport is the mode that most suffers from congestion, and freight transport contributes to the worst situation [2]. Due to this, the search for more sustainable long-haul freight transport is a factor that positively influences the goals cited above, mainly seeking strategies to reduce the share of roadway transport in the modal distribution, improving others such as inland navigation. Given this, governments and policymakers have made efforts to shift freight traffic from road to rail and waterways, particularly in Europe, to support greener modes of transport [3].

A transportation chain is divided into three segments: pre-haul (or first mile), long-haul, and end-haul (or last mile) [4]. In most cases, pre-haul transport and end-haul transport are included in roadway transport (possibly combining different vehicles). In contrast, plenty of different modes can be considered for long-distance transport such as road, rail, air, and water. Moreover, non-road modes of transport can potentially increase their share of freight transport based on internal and external influences (cost, service reliability, capacity, availability) [5]. Also, according to the authors, the water freight transport sector can grow significantly based on the enhancement of the supply and its integration with other modes. These improvements can have a direct impact on logistic chains, such as cost reductions and better efficiency.

Following this, the search for solutions to make freight transport more sustainable has been going on for decades, presenting concepts such as multimodality, intermodality, and—the most recent one—synchronomodality. The multimodal concept is less restrictive [6] since it only requires the inclusion of two or more modes of transport. In this line, the concept of intermodality adds the requirement that the cargo remains in the same cargo unit throughout the journey without the need for extensive handling or repackaging [7]. Even over the years, these solutions do not represent the majority of the total freight share [8]. A model to compare intermodal and synchronomodal transport impacts was created by [9]. A study case on this model found that synchronomodal systems tend to improve the transport service level, capacity utilization, and modal shift but do not specifically reduce delivery costs (lower overall shipping costs and higher handling costs). Due to this, synchronomodality is a possibility to improve the performance of freight [8] in the current era.

### 2.1. Synchronomodality

Synchronomodality, or synchronomodal transport, represents an innovative approach searching to optimize the movement of goods by considering the most efficient and cost-effective transport modes based on real-time conditions. This approach enables opportunities to integrate various transportation modes, such as road, rail, air, and sea, into a synchronized network. The main pillar of synchronomodal transport is to minimize cost, time, and environmental impact while integrating the vehicles' capacity, transportation modes, and customer demands [10]. Synchronomodality involves the decisions of different stake-

holders such as shippers, freight forwarders, and carriers [11], but these decisions are not predefined in advance and are decided using real-time information from the infrastructure and transport providers [7,12].

Synchromodal transport is an important factor in freight movement and logistics, as it presents a more sustainable type of transport [9,13–15], improves benefits from a societal and environmental perspective [9], and allows a smarter utilization of available infrastructure and service resources [12,13,16]. Additionally, even though the origin of synchromodal transportation is related to environmental issues, 70% of the quantitative research focuses only on economic goals [17]. The evolution of the synchromodality concept is shown in Table 1.

**Table 1.** Evolution of the synchromodality concept.

Concept	Source
“Synchromodal freight transportation is positioned as the next step after intermodal and co-modal transportation and involves a structured, efficient, and synchronized combination of two or more transportation modes.”	[18]
“Synchromodal freight transportation involves a structured, efficient, and synchronized combination of two or more transportation modes.”	[4]
“Synchromodal transport considers that the mode choice is made along with the production of the transport service, based on real-time information on the current conditions of the transport system.”	
“Synchromodality encompasses an integrated view of planning and uses different transport modes to provide flexibility in handling transport demand.”	[6]
“Synchromodal freight transport has been hypothesized as having the potential to reduce delivery times, provide better utilization of the capacity of each mode, and improve the alternative modes yielding a more robust transport system.”	
“Synchromodality is the vision of a network of well-synchronized and interconnected transport modes, which together cater to the aggregate transport demand and can dynamically adapt to the individual and instantaneous needs of network users.”	[8]
“Synchromodality is the provision of efficient, reliable, flexible, and sustainable services through the coordination and cooperation of stakeholders and the synchronization of operations within one or more supply chains driven by information and communication technologies (ICT) and intelligent transportation system (ITS) technologies.”	
“Synchromodal transportation is a novel multimodal transportation concept. It builds on a collaboration of shippers and logistic service providers to enable real-time switching between transport modes and mode-free transport bookings, enabling more flexible and sustainable freight transportation.”	[9]
“Synchromodality can be defined by four features: real-time information, flexibility, cooperation and coordination, and synchronization.”	

From Table 1, it is clear that the concept of synchromodality has evolved. Initially, it was described as an efficient and synchronized combination of transportation modes. However, as time passed, the definition expanded to include factors like real-time information, integrated planning, cooperation among stakeholders, and the use of information and communication technologies (ICT) and intelligent transportation system (ITS) technologies. The definitions suggest that the concept is seen as a way to optimize freight transportation while also considering environmental and economic sustainability and reflecting the dependence of synchromodality on the coordination and cooperation of stakeholders in the supply chain, data availability and integration, and technology to improve decision making.

## 2.2. Synchromodality Impacts

The implementation of synchromodality in real life has found numerous challenges [8,12,15]. The global impact of multimodal transport on the supply chain is one of the reasons why

the modal split is so difficult to implement [3]. Indeed, synchromodal systems might imply results regarding the transport system performance in terms of economic, societal, and environmental impacts [9].

- Economic impacts: Total system costs; total system time expense; occupancy of service infrastructure. Compared with multimodal transport, in synchromodal transport, the service line occupancies increase by around 10%, and delivery times decrease by around 8%.
- Societal impacts: Network flows; road traffic. The same comparison implies a reduction of 16% in road transport flow due to the modal shift support.
- Environmental impacts: Emissions. In this study case, there was a 28% reduction in CO<sub>2</sub> emissions.

Moreover, synchromodality can be completely influenced by internal and external issues [5]. The internal issues are related to cost, service reliability and punctuality, capacity available, and industry skill, among others, while the external influences are connected with policies and funding, environmental topics, modification of the supply chain structure, average distances for freight movement, land use planning, etc.

### 2.3. Synchromodality Implementation Challenges

The synchromodal transport challenges were discussed by [15] and were then divided into five different layers: logistics layer, transaction enablers, governance enablers, institutional enablers, and cultural enablers (Table 2).

**Table 2.** Challenges in the implementation of synchromodality.

Layer	Issues
Logistics layer	<ul style="list-style-type: none"> <li>• All resources (stationary and moving) must be continuously aligned with customer demands and needs.</li> <li>• View integration at three levels: network design, integrated service design, and integrated operation and control.</li> </ul>
Transaction enablers	<ul style="list-style-type: none"> <li>• Contracts that allow synchronized transport.</li> <li>• Bigger change for shippers; when they book transport services, the mode of transport is not pre-defined.</li> <li>• The service will be composed based on these preferences and the attributes of the available transport modes.</li> </ul>
Governance enablers	<ul style="list-style-type: none"> <li>• New arrangements for cooperation between agents.</li> <li>• Organizational and legal arrangements focused on the following:               <ol style="list-style-type: none"> <li>(1) The service provider will provide options based on the shippers' preference (service-based); requires stronger collaboration between service providers and shippers.</li> <li>(2) Possibility to consolidate shipments from different shippers.</li> </ol> </li> </ul>
Institutional enablers	<ul style="list-style-type: none"> <li>• From centralized to decentralized organizations.</li> <li>• Institutions might re-think their roles.</li> </ul>
Cultural enabler	<ul style="list-style-type: none"> <li>• Mind shift in transport planning and control mainly to the "mode-free booking" and the shift from "mode-based" to "service-based".</li> </ul>

Source: Adapted from [15].

Regarding the institutions, transportation companies, logistic providers, port authorities and terminals, technology providers, and intermodal terminals are examples of companies that are part of the freight synchromodal decision process. In summary, the challenges in the implementation of synchromodal transport include various and distinct aspects. From a logistics point of view, more than aligning the demand needs, the integration among the transport service levels is quite important. From the transaction,

governance, and institutional enablers, considerable changes are needed, and these changes need to be aligned with the cultural enabler.

### 2.3.1. Strategic, Tactical, and Operational Planning

In addition to the factors mentioned above, synchromodality is also about understanding the stakeholders' preferences. A complete understanding of preferences contributes to reducing costs and improving the service level through the provision of customized services [11]. According to the authors, the most effective transport plan requires complete understanding of the heterogeneity preferences of service from shippers.

A hierarchy of decision problems is discussed in the research performed by [8] that aims to list the challenges found in the implementation of synchromodal freight transport systems (Table 3).

**Table 3.** Hierarchy of decision problems in a Synchromodal Freight Transport System.

Decision Problem	Level	Issue
Synchromodal Network Design	Strategic	First, to define potential corridors and regions for the synchromodal service and to then design the network with possible nodes and connections based on the information available.
Synchromodal Service Pricing Strategies	Strategic	Shippers' involvement—The synchromodal transport service provider has the power to decide which transport modes will be used according to the customer's specifications and the mode availability.
Intermodal Gain Sharing and Contract Design	Tactical	Internal coordination—To define the relevant actors and their different interests, followed by coordination by contract where the incentives for cooperation aim to be shared.
Synchromodal Service Design	Tactical	Decisions about delivery priorities, expected service levels, and packages of synchromodal services are made at this level in addition to the determination of routes and the choice of modality (frequency and capacity analysis).
Operational Resource Scheduling	Operational	It considers transport order details and features and then assigns the orders to the different transport services.
Exception Handling and Real-Time Switching	Operational	Continuous monitoring of the execution, in real-time, checking for unforeseen events and planning corrective actions and adjustments.

Source: Adapted from [8].

Strategic, tactical, and operational planning problems in synchromodality implementation were also taken into account by [4]. Regarding strategic planning problems, the authors cited problems such as mode definition, multi-commodity, allocation, direct shipment, capacity, transshipment, and schedule issues, among others. Also, there are issues related to fixed schedules, assets, empty flows, elastic demand, split delivery, additional scheduling issues, synchronization, and decentralized decision making in tactical and operational planning problems.

### 2.3.2. Frequency and Flexibility

Among the three most common means of freight transport (roadway, railway, and waterway), rail or water transport is generally cheaper and more environmentally friendly, but its services are not as frequent and fast as road travel, causing a lack of flexibility in delivery quantity, frequency, and schedule [3]. As a result of this, logistics operators tend to consider that these modes can negatively impact the supply chain. According to [15], the modal choice among the three options will be based on the relative importance of transport time and costs.



The main risk of synchromodal transportation is the limited, or fixed, schedules of the transport modes because this decreases its flexibility [10]. In this line, a good synchronization of services provided by the different modes of transport, adding complementary information about the inland terminals' services (transshipment and storage information) is one way to reduce waiting times and overall transportation costs (eliminating intermediate storage, for example) [15].

### 2.3.3. Cooperation and Coordination

The concept of synchromodality, which proposes the efficiency and flexibility of transport, is built considering cooperation among all stakeholders along the transport chain [12]. So far, there are numerous challenges in implementing synchromodality because it requires collaboration and coordination between different stakeholders and a constant sharing and monitoring of information.

The manner of cooperation between the parts involved, as well as the acceptance of a central network organizer, is one of the many inconsistencies existing in the area of synchromodal transportation [7]. Other researchers talk about horizontal cooperation, real-time changes, and necessary mind-shift as barriers to synchromodal transportation [15].

Moreover, it is important to set up standards for data sharing between stakeholders, ensuring the high quality and veracity of information [12], so this stakeholder collaboration could promote on-time delivery and the integration of different levels of planning tending to provide more reliability, flexibility, and sustainability [4,12].

Regarding the cultural issue, [17] states that synchromodality is one of the main topics in discussions about sustainable transport logistics; however, awareness among stakeholders needs to be strengthened. Additionally, beyond collaboration, active participation in the process of a mental shift is required by the involved parties to ensure the necessary freedom for fulfilling a-modal transport services [12].

### 2.3.4. Synchronization

Based on the three dimensions of synchromodality defined by [8], the triggers of synchronization in each one were defined by [19] as follows:

- Moving resources: Service schedule, vehicle capacity and availability, operating hours.
- Customer demands: Size, pick-up and delivery time windows, delivery due time.
- Stationary resources: Link availability, terminal capacity, terminal operating hours.

A technical challenge of synchronization involves the implementation of integrated information solutions to minimize container wait times at origin terminals and waiting times for transport services at destination points [8]. In unplanned cases, the transshipment between modes or loading and unloading the cargo could take hours of waiting. A modal considering constraints was created by [8] in favor of determining an optimal schedule of multiple transport modalities for a specific time. It considered constraints regarding capacity, flow, delivery time, service sequence, and infrastructure usage. Consequently, it offers a comprehensive depiction of the constraints associated with the operational synchronization of both moving and stationary resources. An approach that considers estimations of the demand and focuses on planning truck flow and barge schedules is also considered [20].

From the perspective of a shipper who wants to transport a specific freight from an origin to a destination, minimizing transport costs, the "a-modal" reservation approach enables the transportation provider to determine the transportation modes and vehicles to be employed in a specific transportation request, so the shipper buys the transport service (no a-slot in a specific mode) [21,22]. Additionally, it allows the service provider to make any adjustments during the route. From a synchromodal transport point of view, the time of decisions realized at the tactical level becomes closer to the time of decisions at the operational level [6] when the route and mode definition can be replanned based on online information [21]. In this case, solutions that consider a prediction of traffic levels, constraints existent, and transport options available have been on focus to a more practical

sychromodality approach [8,20–22] by using models that provide different scenarios of mode shift based on cost and time calculations, among other factors.

#### 2.4. Main Findings of the Literature Study

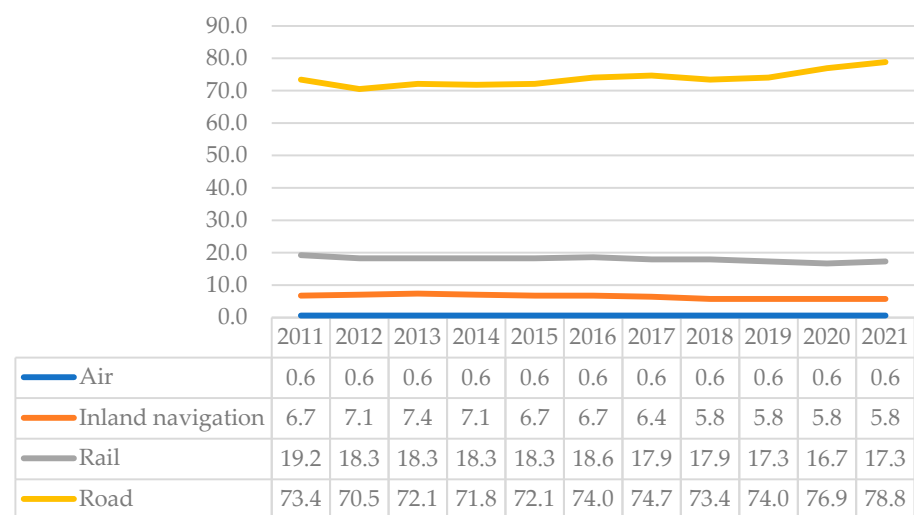
In summary, the literature review reinforces that synchronomodality offers significant promised for enhancing the sustainability and efficiency of freight transportation, but there are substantial issues in its implementation. The main conclusions about the concept, impacts, and challenges of this section can be summarized as follows:

- (i) The synchronomodality concept supports mode integration and dynamic mode switching based on current transport conditions.
- (ii) Synchronomodality has the potential to reduce costs, reduce times, and support a modal shift away from road transport, consequently alleviating congestion and reducing emissions.
- (iii) Besides other challenges, the implementation of synchronomodality deals with real-time information and decision making.

In this line, this paper contributes to closing the gap between the synchronomodality concept and practice, mainly regarding challenges and limitations associated with the implementation in real life, from the perspective of transport experts in the Flanders.

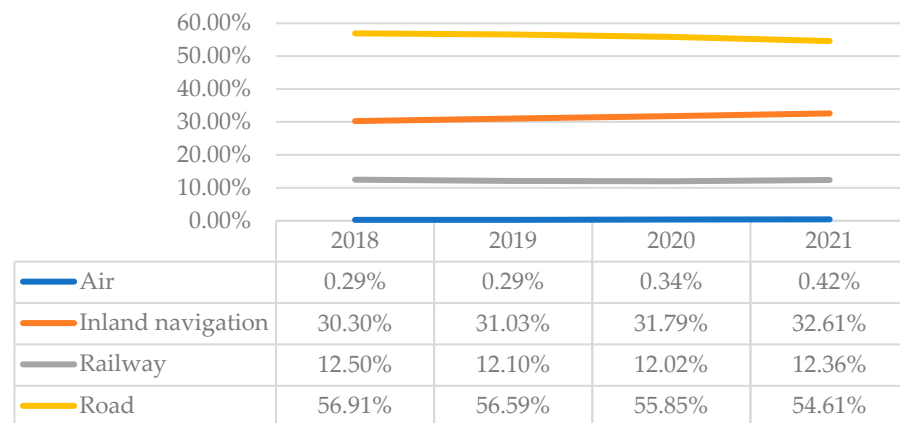
### 3. Case Study Setting

The largest part of inland cargo transportation in the EU is completed by road. The inland freight modal transport split within the EU countries has not behaved as expected. The cargo transported by roadway increased from 73.4% to 78.8% between 2011 and 2021, while a decrease was noted in the inland waterway cargo transport during the same period (from 6.7% to 5.8%) [23]. This fact goes against the issues of sustainable freight transport issues discussed in recent years. The modal split in EU countries is shown in Figure 1. This indicator is defined as the percentage of each mode of transport in the total transport performance measured in tonne-kilometer (tkm).



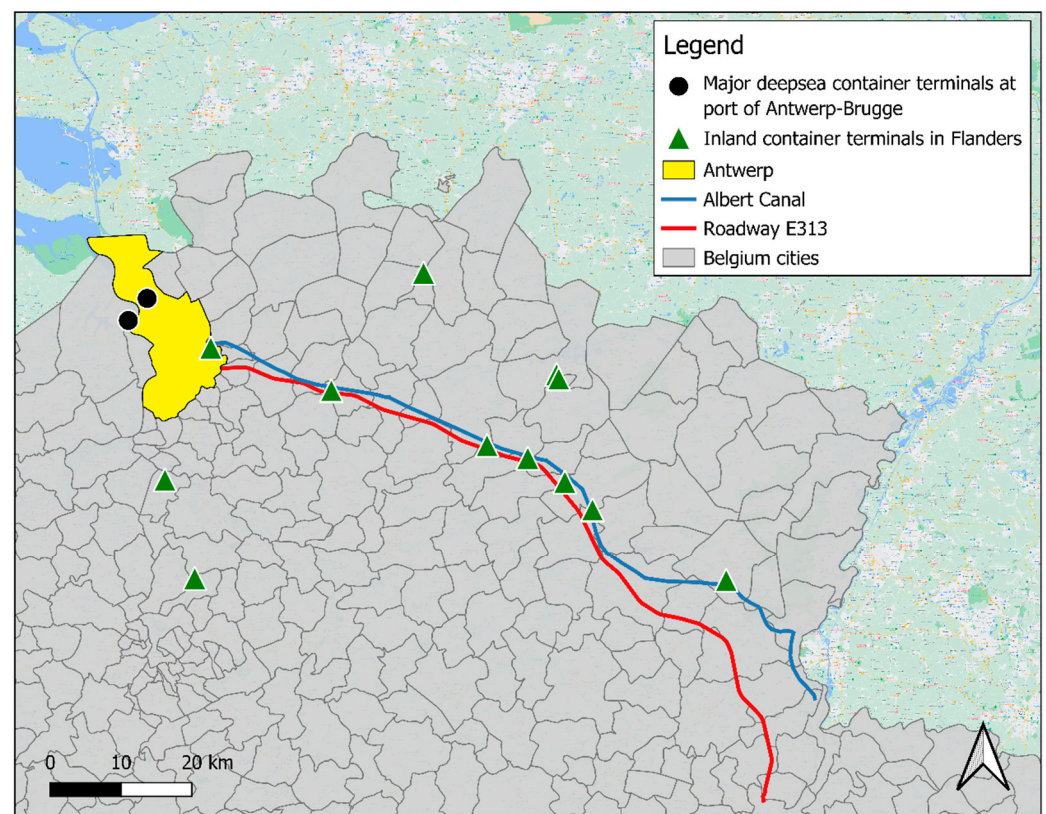
**Figure 1.** Percentage of the modal split of freight transport in the European Union (EU). Source: [23].

Specific to Belgium, Infrabel data available in 2023 show the annual evolution of the percentage transported by rail, road, inland navigation, and air (Figure 2). The evolution of the modal split is calculated based on the transported weight (net). We observe that there is an indication of a decrease in the share of IWT in Europe. It is also important to notice that the roadway information relates only to Belgian trucks. The data on freight transport by road consider the vehicles registered in Belgium with a payload of at least 1 ton and the data about the inland navigation of goods consider all vessels in Belgian inland waterways. In other words, the general quantity of trucks, or the modal share for the road, is higher.



**Figure 2.** Evolution of the modal split based on the weight transported (net). Source: [24].

Moreover, Antwerp is a port city located in Belgium, Flanders, very well-known because of its port activities [25]. The port in question is the Port of Antwerp-Bruges, the second largest port in Europe, and the corridor of roadway E313 is one of the most well-known ways to get there. On the other hand, there is also the Albert Canal, a waterway following almost the same design as the E313 roadway. In Figure 3, it is possible to see both ways.



**Figure 3.** Description of the study region.

An implemented Kilometer Charge System (KCS) defines that heavy freight vehicles of more than 3.5 tons circulating in Belgian territory have to have installed specific equipment that collects the location of the truck every 30 s [26]. One week of truck global positioning system (GPS) data, from 2021 (15th to the 21st of November), made available by [27], show that around 32% of truck movements (units) in the sample cross the border going to or leaving another country. From a synchromodality point of view, due to long-distance



transport, these trucks are a potential target to instigate modal shift (mainly using IWT); they also have more flexibility on the route and the availability of modes. The largest part of these trucks targets the port of Antwerp-Bruges.

#### 4. Research Approach

Alongside the Albert Canal, there are multiple inland terminals that can be seen as secondary ports, where goods can be transshipped from one mode to another mode. Around these inland terminals, which are enclosed by multiple modes, including the E313 road, there is often a concentration of multiple distribution centers and industrial activities. However, roadway freight transport is still the majority in the region.

This paper treats synchromodality as a pilot case in the Antwerp region, mainly the scenario of roadway E313 and Albert Canal. But, owing to the Flanders region having separated management systems for each transport mode (roadway and waterway, in this case), the solution proposes a common system, considering highways and waterways, in which it will be possible to see information about both systems at the same time.

Knowing all the challenges to the implementation of synchromodality in real life, the main barrier is understanding which information is needed to make the synchromodal concept feasible in Flanders; in other words, what is needed to make a real-time mode shift in this study case. To achieve this, the methodology proposed by this research uses a FG and interviews with transportation professionals in the Flanders region.

In this case, the FG method offers a multifaceted approach from several points of view and was chosen to comprehend the requirements of synchromodality in real life using specialist experiences. Firstly, the interactive nature of FGs encourages dynamic discussions among participants, enabling a rich exchange of diverse perspectives and ensuring a comprehensive exploration of aspects of synchromodal transportation. Moreover, it also allows the identification of shared concerns and priorities regarding the requirements of different entities involved in synchromodality, such as logistics providers, shippers, and transportation authorities.

The FG took place on the 6th of July 2023 in Antwerp and put together experts in the transportation domain in Flanders. In the framework of the meeting, the innovative features of synchromodality were presented and a discussion was held on the subject of existing traffic management systems, possible benefits and problems of implementing innovative traffic management systems, and the factors that hinder the prospects of implementing new systems. Roadway and waterway traffic management company representatives were invited to join the discussion. Some of the experts were also interviewed after the FG and questioned mainly regarding the current management system.

A point to be taken into account for the effective implementation of the system is to conquer the market, influencing the cargo transport operators, terminals, and infrastructure administrators to use the solution instead of the old practices. So, a new technology, engulfing roadway and waterway infrastructure information, should firstly focus on dissemination and divulgation to stakeholders of the entire logistics chain to mainly understand the advantages of having this platform and also to engage them on this topic.

#### 5. Results and Discussion

The FG was structured by combining 12 different specialists in the field, as follows:

- (1) Representant from the waterway traffic,
- (2) Representant from the roadway traffic,
- (3) Representants from inland terminals,
- (4) Representants from logistics and transport companies,
- (5) Representant from the port,
- (6) Representants from the research side applied to freight transport using waterways.

The discussion was divided into three sections: (1) an overview presentation of synchromodality's role in Flanders, (2) a discussion about the current traffic management systems and the challenges that transport operators have to deal with daily, and (3) a

discussion about the recommended solutions and how they will contribute in the future traffic management of cargo from road transport to water corridor transport.

The biggest discussion within the FG, considered a threat, is real-time decision making. The experts declared that in the current situation, it is not feasible to make the freight decision in real-time (i.e., a modal shift from roadway to inland waterway transport (IWT) due to accidents and congestion). Some responsible factors for this include the following:

- The number of transfer points (inland waterway terminals) is limited, as well as their capacity, work hours, and response time. Then, if determined transport starts its journey by roadway, there are limited possibilities for transshipment to IWT;
- If the service providers have not planned the activity, it could take hours, or even days, to shift the cargo from a truck to a barge, and the capacity is limited too;
- Normally the inland waterway terminal work is planned in advance; in case of a different approach, this also has to be modified;
- Most part of the time, the truck has one freight in one direction and another freight on the return. In the case of real-time modal shifts due to accidents or congestion, the truck will likewise have to endure the wait time or will lose the return freight;
- Waterway transport is still slower than roadway transport, even considering waiting times in traffic jams.

Based on this information, the solution discussed between the experts was that synchromodal technology should work better in practice if based on forecast real-time traffic conditions for the departure date (2–3 days in advance). Then, the freight operator could decide the most affordable freight transport, based on historic data and updated infrastructure information. This approach will highlight the waterway infrastructure and freight waterway transport and induce a shift from the roadway to IWT. The Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis constructed based on the FG is shown in Table 4.

**Table 4.** Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis.

Strengths	Weaknesses
<ul style="list-style-type: none"> <li>- Nowadays, in the Antwerp region, a common system does not exist combining information from the roadway, waterway, and other infrastructure providers; the synchromodality technology's main advantage is proposing one system encompassing all of this information together.</li> </ul>	<ul style="list-style-type: none"> <li>- The transport operators, truck companies, terminals, and infrastructure managers already have their communication channels.</li> </ul>
Opportunities	Threats
<ul style="list-style-type: none"> <li>- This solution could be the pioneer, in the region, in involving freight operators and infrastructure providers (roadway and waterway) on the same platform.</li> <li>- Could also be the main tool for forecasting, planning freight transport, and for better usage of the available infrastructure (mode choice).</li> </ul>	<ul style="list-style-type: none"> <li>- Real-time prediction gaps. The changing of some parameters between the decision and the action.</li> <li>- Collaboration with stakeholders is necessary for synchromodality's proper functioning.</li> </ul>

The main insight from the FG was related to the real-time conditions based on prediction. In this line, freight operators could use the synchromodality tool to see, in the near future, what is the best mode option based on the projection of the delay/congestion and decide if it is worthwhile to make a shift from the roadway to IWT.

Moreover, regarding potential conflicts between stakeholders, occasionally, there may be a conflict in the freight transport chain, particularly regarding truck and barge operators. For example, truck operators may lose income by transferring a container to an inland

terminal. However, each actor must understand the general benefits of synchronomodality to the freight transport logistics ecosystem.

After the completion of the FG, a SWOT analysis was conducted to comprehensively evaluate and identify internal and external factors that can impact the success of synchronomodality in real life. Three specialists, chosen from among the FG participants, were interviewed: one with a lot of experience in roadway transport operation and management (EXP1), one with a lot of experience in waterway transport (EXP2) and operation and management, and one with both experiences (EXP3).

Based on their experiences in freight transport, the interviewees were asked about the existing traffic management system in which they have experience. In this case, traffic management issues mean challenges and problems that arise in the effective management and control of traffic flow on roadways, waterways, and other transportation networks, such as congestion, capacity limitations, traffic optimization, safety concerns, incident management, emerging technologies, integration, etc. Table 5 gives a perspective of the current roadway and waterway traffic management system; the evaluation system ranges from Very Poor, Poor, Acceptable, Good, to Very Good.

**Table 5.** Interview answers about the traffic management system.

Questions/System Experience	EXP1	EXP2	EXP3	
	Roadway	Waterway	Roadway	Waterway
The current cooperation level among transport stakeholders for traffic management issues is	Poor	Poor	Acceptable	Poor
The flow of data among the transport stakeholders toward efficient traffic management is	Poor	Poor	Acceptable	Poor
The trust of end users in existing traffic management systems is	NR *	Poor	Poor	Poor
The response time of the current traffic management system during severe weather conditions is	Acceptable	Acceptable	Acceptable	Poor
The response time of the current traffic management system during planned events is	Good	Acceptable	Acceptable	Poor
The response time of the current traffic management system during traffic congestion is	Good	Acceptable	Acceptable	Acceptable
The adequate legislation for the implementation of an integrated traffic management system is	NR *	Very poor	Acceptable	Poor
The existing staff training for operating advanced traffic management systems is	NR *	Poor	Poor	Poor
The existing data update of the traffic management systems is	Good	Poor	Poor	Poor

\*NR = No replies.

Another interesting point is that the interviewees affirmed that the companies they know always try to remain updated on new technologies/traffic solutions. So, new technologies are welcome in daily activities. These interviews allow us to identify a gap in the current systems mainly regarding the confidence of end users in the current traffic management systems and the knowledge of operators about advanced traffic management systems.

More than the challenges identified in the literature, it was possible to identify the challenges of synchronomodality implementation in a real-life perception (real-time decisions, freight decision time, communication between stakeholders, and availability of infrastructure and information, among others) and obtain an overview of the current freight transport situation. It is possible to see that there is space (gaps) for improvement in the

current traffic systems (roadway and waterway) and also that a tool combining both pieces of information is missing to highlight the IWT.

## 6. Conclusions

The literature over the past decades highlights the need for sustainable transport solutions in the face of traffic issues and environmental concerns. The largest part of freight transport is by roadway, and a modal shift to a more sustainable mode has been an area of focus. In this way, synchromodality offers the potential to optimize freight transportation dynamically using real-time information and integrated technology.

The concept of synchromodality represents an innovative approach to making long-haul freight transport more sustainable and efficient. Synchromodality has the potential to increase the attractiveness of more sustainable transport modalities and improve the modal shift since it presents the cost and resource efficiency, better resilience of transport, connectivity of infrastructure, and collaboration among the involved stakeholders [17]. In conclusion, synchromodality, when properly implemented, contributes to sustainability in the freight transport chain by optimizing transportation networks and encouraging the use of more environmental modes, such as waterways.

In this case, synchromodality inherently contributes to sustainability since it helps to reduce congestion in specific transportation routes and its respective radiation to other areas and to reduce overall emissions and resource consumption (or better utilization of resources). Flanders, with its strategic location and transportation network, is a potential scenario for implementation. However, the path to making synchromodality a reality in Flanders has various challenges, as discussed in this paper through a qualitative study combining FG discussions and interviews.

Besides the fact that synchromodality involves the coordination of multiple stakeholders such as shippers, freight forwarders, and carriers, in addition to its connected and integrated information, the bigger challenge found in his paper was the real-time decision making. Insights from the experts show two important points: the current system needs improvement, and in the current situation, it is not feasible to make the freight decision in real-time, for example, a modal shift from roadway to IWT, because of all the limitations in moving and stationary resources.

However, synchromodality could be feasible if planned based on forecast real-time traffic conditions for the departure date. This strategy of prediction is also cited in the literature [8,20–22]. Subsequently, the cargo operator would have the opportunity to select the most cost-effective freight transportation option, forecast based on historical data and current infrastructure details, and could decide on any modal shift in the journey. Also, infrastructure managers could collect freight flow data to keep the forecasts up to date. This strategy would enhance the visibility and utilization of waterway infrastructure.

This paper's approach serves as the foundation for integrating research findings and practical insights, paving the way for realizing the synchromodal concept in Flanders. This research contributes significantly to the field of synchromodality through a qualitative study and also provides valuable guidance for decision makers and stakeholders in understanding the essential prerequisites for achieving a more synchronized, flexible, and sustainable approach to long-haul freight logistics.

In conclusion, the follow-up steps of our research involve the development of a comprehensive prediction model for both roadway and waterway systems, focusing on simulating scenarios considering parameters such as time and costs. This model aims to provide an understanding of the dynamic between transportation modes and routes. By using historical data, the predictive model will be able to forecast traffic patterns, potential bottlenecks, and waterway conditions. Additionally, to understand the percentage of mode shifts based on forecasted traffic conditions, we plan to conduct a survey of specialists to understand their preferences and priorities.

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