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AUTOFLEX

[D2.2] Market analysis

Work Package	WP2	From modal shift barriers to design parameter quantification
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EXECUTIVE SUMMARY

This study examines transport demand in the Dutch and Belgian AUTOFLEX application areas, analyzing three modes of transport: Road transport, inland waterway transport (IWW) and rail transport. The data compiled sources from Eurostat and the national statistics offices of the Netherlands and Belgium and refers to the year 2022. The analysis focuses on freight transport, which includes both domestic and cross-border transport.

The AUTOFLEX regions include the Randstad region in the Netherlands (NUTS2 NL32 and NL33) and the Ghent area in Belgium (NUTS2 BE21 and BE23). The study identifies and compares the traffic flows across the different transport modes and shows the aggregated NST categories for the classification of goods for the sake of identifying a potential for the newly planned IWW services in the context of AUTOFLEX.

The study finds that road transport in the Netherlands comprises 666 million tonnes and in Belgium 444 million tonnes of transported goods. IWW traffic in the Netherlands amounted to 356 million tonnes, while Belgium recorded 216 million tonnes. The results show that different types of goods are transported via both roads and inland waterways, indicating potential for modal shift.

Regarding the observed transport of different commodity groups, a clear picture cannot be obtained. It is not the case that IWW dominates bulk cargo, unitized cargo is present as well. The large oversea ports Rotterdam and Antwerp dominate the cargo flows in terms of their massive container in- and outflows.

The analysis regarding modal choice options highlights the strengths and weaknesses of road and IWW. While road transport offers high flexibility and short transport times, IWW has a better energy efficiency and lower operating cost. Quality indicators as motives for modal choice are introduced that play a role besides the always predominant costs considerations. The study emphasizes the need to promote different transport options to increase efficiency and to meet different market needs. The roles of the different actors in modal choice are explained.

In summary, the study shows that there is a significant opportunity for a modal shift from road to inland waterways, especially in the relevant regions of AUTOFLEX applications. Besides costs which could be very competitive in the case of autonomous barges, quality issues to meet include flexibility and frequency, which could be achieved with a higher number of smaller vessels operating also on CEMT Waterclass 2 inland waterways. Future analyses should focus on the development of specific strategies to support this shift.

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TABLE OF CONTENTS

Funded by the European Union
Grant Agreement: 101136257

Funded by the European Union
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TABLE OF FIGURES

Funded by the European Union
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TABLE OF TABLES

LIST OF ABBREVIATIONS

Abbreviation	Description
AAB	AUTOFLEX Advisory Board
CA	Consortium Agreement
CBS	Centraal Bureau voor de Statistiek Nederland
CEMT	European Conference of Ministers of Transport
CT	Combined Transport
DoW	Description of Work
EU	European Union
IWT	Inland Waterway Transport
IWW	Inland Waterways
JIT	Just-in-Time
NST	Nomenclature uniforme des marchandises pour les statistiques de transport
NUTS	Nomenclature of Territorial Units for Statistics
OD	Origin-Destination
SOTA	State-of-the-art
t	Tonnes
TCO	Total Cost of Ownership
TEU	Twenty-foot Equivalent Unit
tkm	Ton-kilometres
WP	Work Package

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1 INTRODUCTION

The primary purpose of this deliverable is to assess the transport demand in order to establish a baseline and forecast potential modal shifts in cargo transport from road to IWW transport. This analysis is crucial for understanding how transport volumes can be redistributed among different modes, which is essential for developing more sustainable and efficient transport systems.

Specifically, this study focuses on the potential for shifting cargo volumes from road transport to inland waterways (IWW). By analyzing the current transport demand and identifying the criteria that influence mode selection among shippers, as well as the factors driving investment decisions by transport asset owners, the study aims to provide actionable insights that can inform transport policy and planning.

This investigation is particularly pertinent in the context of the Dutch and Belgian AUTOFLEX use case areas. As these regions are characterized by dense transport networks and significant cargo movements, understanding the dynamics of transport demand will enable stakeholders to identify opportunities for enhancing modal shifts, thereby contributing to environmental sustainability and optimizing logistics operations.

In addition to evaluating the potential for modal shifts, the study will also address existing barriers and limitations that may hinder the transition from road to IWW. By utilizing data from relevant national statistics and Eurostat, the study will provide a comprehensive overview of current transport patterns, focusing on the year 2022, which is the most recent year for which data is available.

Through this deliverable, stakeholders - including policymakers, transport operators, and logistics companies - will gain a deeper understanding of the factors influencing modal choices and the potential for integrating more inland waterway transport solutions into existing logistics frameworks. This knowledge is vital for fostering a competitive transport market that is responsive to the needs of shippers while also minimizing environmental impact.

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2 POTENTIAL FOR MODAL SHIFT

2.1 PURPOSE OF THE STUDY

According to Task 2.2 of the AUTOFLEX project, this study aims at modelling the transport demand to provide a baseline and an outlook for modal shift potential. Specifically, the potential of a shift of cargo volumes from road to waterborne transport is analyzed. Furthermore, the study identifies mode selection criteria for transport market actors.

2.2 DATA SOURCES AND DATA LIMITATIONS

The study focuses on the transport demand in the Dutch and Belgian AUTOFLEX use case areas which will be defined later in this chapter. Three modes of transport were analyzed: Road, inland waterways (IWW), and rail transport. Data sources have been Eurostat, the Dutch national bureau of statistics and its Belgian national equivalent. The analysis was restricted to the year 2022, which was the most recent year available in the data. For the classification of cargo, an aggregation of NST 2007 categories was used based on the available data of the Dutch national bureau of statistics. Throughout the analysis, the aggregations are referred to as NST aggregates.

Table 2-1: Aggregated NST Categories according to CBS Netherlands *labels were renamed for readability purposes

NST Code	Contains NST2007 categories:	NST Description	Aggregate label*
NSTCAT1	NST 01 and NST 04	Agriculture and food	Agricultural products
NSTCAT2	NST 02 and NST 07	Petroleum, fuels	Fossil fuels
NSTCAT3	NST 08	Chemicals	Chemicals
NSTCAT4	NST 03 and NST 09	Sand/soil, building materials	Building materials
NSTCAT5	NST 05, NST 06 and NST 10	Wood/paper, textiles, metal	Forestry, textiles, metals
NSTCAT6	NST 11, NST 12 and NST 13	Machinery, transport equipment and furniture	Machinery, transport equipment
NSTCAT7	NST 14	Waste	Waste
NSTCAT8	NST 15 to NST 20	Groupage, Moving goods, sea containers	Miscellaneous

The transport demand in the Netherlands and Belgium encompasses domestic transport as well as transport to and from these countries. For the purposes of this study, these transport demands are summarized as transport of the Netherlands and transport of Belgium.

Geographically, the available data follows the Nomenclature of territorial units for statistics (NUTS) of the European Union (EU). NUTS regions have four different levels. Starting at NUTS0 which refers to the national territory of a state, i.e. the Netherlands and Belgium in the case of this study, they gradually become more fine-grained with each level. NUTS1 are major socio-economic regions, for instance “West-Nederland”. NUTS2 specifies administrative regions, for instance “North-Holland”. NUTS3 marks the most granular

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distinction with small geographical regions, for instance "Greater Amsterdam". The NUTS classifications used for this study can be found in the annex. For more information on NUTS classification please refer to Eurostat (Overview - Eurostat (europa.eu)). Origins and destinations of a given transport as well as regions of loading and unloading of goods are classified according to the NUTS regions they are contained in. For this study, NUTS2 and NUTS3 regions were considered.

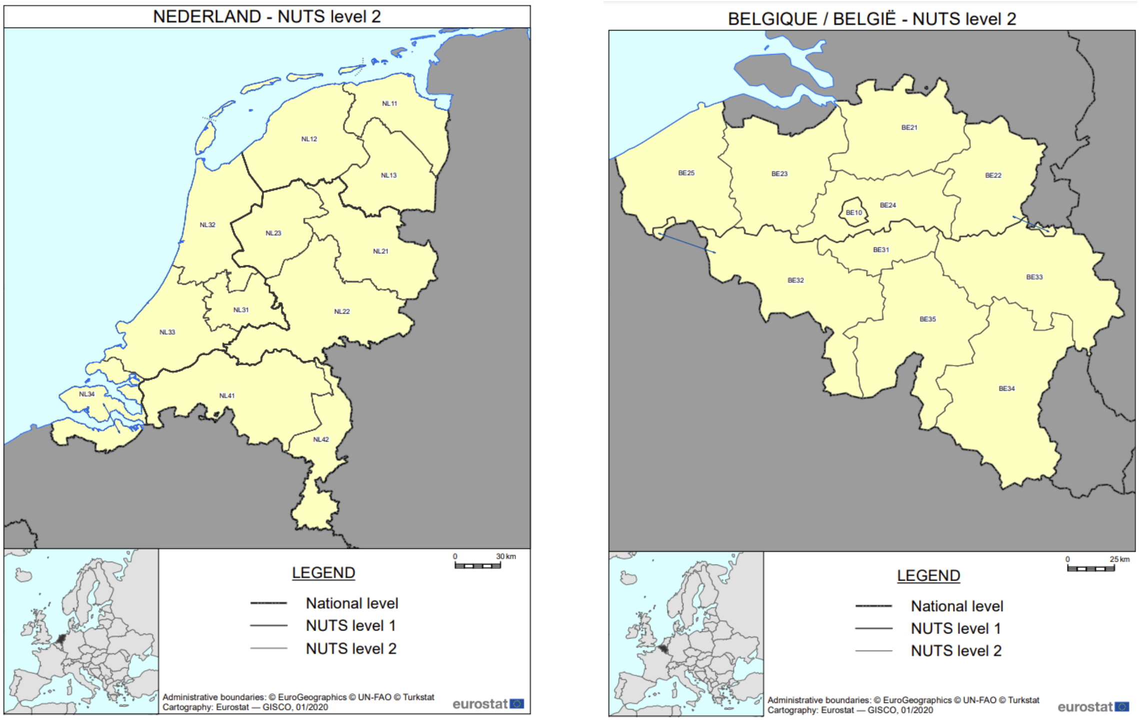

Figure 2-1: Dutch and Belgian Nuts 2 regions, Source: Eurostat

AUTOFLEX encompasses two use cases. The first use case is situated in the Netherlands in the Randstad Holland region between Rotterdam and Amsterdam. The corresponding NUTS2 regions are NL32 and NL33. The second use case is situated in Belgium around the city of Ghent, including NUTS2 regions BE21 and BE23. The listed NUTS2 regions will be referred to as the AUTOFLEX region in the remaining study.

In the following the obtained datasets are presented.

2.2.1. ROAD TRANSPORT

For the Netherlands the following datasets from the year 2022 were obtained from the Dutch national bureau of statistics (CBS) upon request:

- Traffic matrix restricted to vehicles registered in the Netherlands on a NUTS2 level for origin-destination pairs from, to and within the Netherlands with aggregated NST classification and their respective volume in t.
- Traffic matrix restricted to vehicles registered in the Netherlands on NUTS3 level for origin-destination pairs from, to and within the Netherlands and the volume in t but without NST classification.

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- Traffic matrix restricted to vehicles registered outside of the Netherlands on a NUTS2 level for origin-destination pairs from, to and within the Netherlands with aggregated NST classification and their respective volume in t.

For Belgium, data in the form of a traffic matrix could not be obtained. The data for Belgium, stemmed from the Eurostat dataset "road_go_na_rl3g" of the year 2022:

- National road freight transport in t by region of loading on NUTS3 level.
- National road freight transport in t by region of unloading on NUTS3 level.

National road freight transport refers to the goods transported by nationally registered vehicles. The transport may be on the national territory or outside of it. The same dataset includes data on Dutch loading and unloading volumes. This data was used complementary to the data from CBS in the analysis of Dutch traffic.

The goal of the data analysis was to get a detailed overview of transport flows that includes cargo classification on a NUTS3 level. The methodology will be elaborated further on in the following chapter.

2.2.2. INLAND WATERWAYS TRANSPORT

The available dataset for both the Netherlands and Belgium on cargo flows on inland waterways (IWW) was the Eurostat table "iww_go_atygofl" from the years 2019 to 2022 which included:

- A traffic matrix on a NUTS2 level for origin-destination pairs with NST classification and their respective volume in t for Belgium and the Netherlands.

The data was collected nationally and considers all inland waterway transport within the respective national territory, regardless of their country of origin or place of first loading and final unloading.

The scope of the data analysis was to obtain a detailed overview of transport flows which can be compared to the one of road transport. The methodology is described in Section 2.2.5.

2.2.3. RAIL TRANSPORT

For the Netherlands, the following datasets from the year 2019 (most recent available dataset) were obtained from CBS:

- Traffic matrix on a NUTS2/NUTS0 level for origin-destination pairs from, to and within the Netherlands with NST classification and their respective volume in t.
- Traffic matrix on NUTS3 level for origin-destination pairs from, to and within the Netherlands and the volume in t but without NST classification.
- Traffic matrix on a NUTS2 level for origin-destination pairs from, to and within the Netherlands with transported containers and their respective volume in t and in TEU.

Data with the same base year as the road and IWW data (2022) could not be obtained. Further, the datasets did not contain clear NUTS2 or NUTS3 connections but only NUTS0 country codes for all countries outside of the Netherlands. Thus, for most origin-destination pairs either the origin or the destination could not be clearly identified.

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For Belgium no data on rail transport could be obtained, neither through the national office of statistics nor through Eurostat. While information on the cargo volumes transported by rail would present a useful supplement to contribute to a more complete picture of cargo movements in and out of the use case areas, the scope of this analysis was a potential modal shift from road to IWW, rather than from rail to IWW or from road to rail. Given the described lack of data and the focus on road to IWW shift, an exploration of rail data was omitted in the further analysis.

2.2.4. LIMITATIONS

The available datasets on road and IWW, as well as the incomplete data on rail represent limitations for the analysis.

For the Netherlands data on cargo flows on road and IWW could be obtained from the databases of CBS and Eurostat. For Belgium, data on the cargo flows of IWW could be obtained from Eurostat. Road transport data is restricted to the data provided by Eurostat, which consists of national road freight transport by region of loading and unloading. This made a direct comparison between road and IWW for Belgian origin-destination pairs (OD-Pairs) challenging. Therefore, the in-depth analysis focused on the Netherlands. Inferences about Belgium may be drawn from OD-Pairs that are going to and coming from Belgium to the Netherlands. Moreover, general patterns in the road transport of Belgium could be deduced from the available data. For a direct comparison of Belgian IWW and road transport more congruent data would have been necessary.

The analysis was restricted to the most recent year available, 2022. Thus, it cannot display trends in cargo flows over time. However, the analysis aimed at evaluating the potential for a modal shift, meaning the scope is understanding the underlying mechanics behind mode choices, which manifest themselves in differences in cargo volumes between road and IWW transport flows. As these comparisons are meant to show general transport market characteristics, a trend analysis was less relevant for the task at hand.

A further limitation is the aggregation of NST classifications. Since relevant data was only available in the form of aggregations, the analysis was restricted to those aggregates and could not display a more detailed distribution of goods.

Moreover, it should be noted that the statistical data relies on voluntary surveys of the relevant stakeholders. It represents tendencies within the field and an approximation of the actual cargo flows, but it does not necessarily depict the reality of the current state of transportation in the Netherlands and Belgium. All operations performed with the data must be treated as approximations and do not allow for definite conclusions about current cargo flows. However, throughout the description of the data general patterns are visible, which give an indication about differences between cargo flows on road and on IWW. Drawing from these patterns, inferences about the potential of a modal shift from road to IWW can be made. The deduced patterns in the statistical data will be supported by the literature review to obtain robust results.

2.2.5. NOTE ON MISCELLANEOUS GOODS

The NST2007 definition for classifying goods in freight transport has 20 divisions on its first level. The divisions 1-14 can be associated with the actual goods being transported. The available Dutch statistics uses aggregates of the divisions and calls the NST 2007 divisions

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15-20 in a joint definition groupage, removal goods, sea containers. In this report the term miscellaneous articles is used for this aggregate. The divisions 15-20 are defined as follows:

15 - Mail, parcels

16 - Equipment and material utilized in the transport of goods

17 - Goods moved in the course of household and office removals; baggage and articles accompanying travellers; motor vehicles being moved for repair; other non-market goods n.e.c.

18 - Grouped goods: a mixture of types of goods which are transported together

19 - Unidentifiable goods: goods which for any reason cannot be identified and therefore cannot be assigned to groups 01-16.

20 - Other goods n.e.c.

The differentiation between divisions 19 and 20 is only to be explained if one investigates the sub-groups of division 19, which are defined as follows:

19.1 - Unidentifiable goods in containers or swap bodies

19.2 - Other unidentifiable goods

This means that all unitized cargo in intermodal transport units (ITU) should be found in division 19, if rightly classified. However, national transport statistics rely on compulsory questionnaires that transport actors must answer. The easiest and fastest way to do this is to tick a box as undefined or other goods. Cargo from semi-trailers or any groupage can also be found in 20, also because the differentiation between 19.2 and 20 remains difficult.

2.3 METHODOLOGY

In order to identify potential commodities to be potentially shifted from road to inland waterways (IWW), the available data presented in Section 2.2 for both transport modes was examined and compared.

2.3.1. ROAD TRANSPORT

For the Netherlands, the aim of the analysis regarding road transport was to determine a classification according to the NST aggregates for the transported volumes on a NUTS3 level. The available data on road transport obtained through CBS and Eurostat, does not include a traffic matrix with NST aggregates on NUTS3 level, but it contains fragments of the required information, which can be combined to obtain a classification according to the NST aggregates. For the classification, only goods transported by vehicles registered in the Netherlands were considered, since for foreign vehicles no data on a NUTS3 level was available.

The process of attaining the NST aggregates and their volumes on NUTS3 level is visualized in Figure 2-2:. The datasets available through CBS, with NST classifications and volumes on a NUTS2 level and volumes on a NUTS3 level were compared against each other to find matches and determine potential candidates. Subsequently, the available Eurostat datasets on national road freight transport were used to derive distributions of NST aggregates per NUTS3 region. The result is a traffic matrix containing origin-destination pairs on NUTS3 level with the respective volume in t per NST aggregate.

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For Belgium, road data could not be obtained in the form of a traffic matrix with origin-destination pairs (see Section 2.2). The only available data sets were those on the national road freight transport by region of loading and unloading, which were drawn upon for the classification of cargo in the case of the Netherlands. For this analysis, the two datasets were filtered to contain only regions within Belgium and aggregated according to the NST aggregates described in Section 2.2.5. In order to estimate the total volume of cargo "turnover" for Belgian transport, the total volumes of both datasets were added up. These total volumes are comparable to the Dutch data. A region of loading corresponds to a Belgian origin. A region of unloading to a Belgian destination. Therefore, while the exact origin-destination pair might not be known, the volumes transported can be estimated.

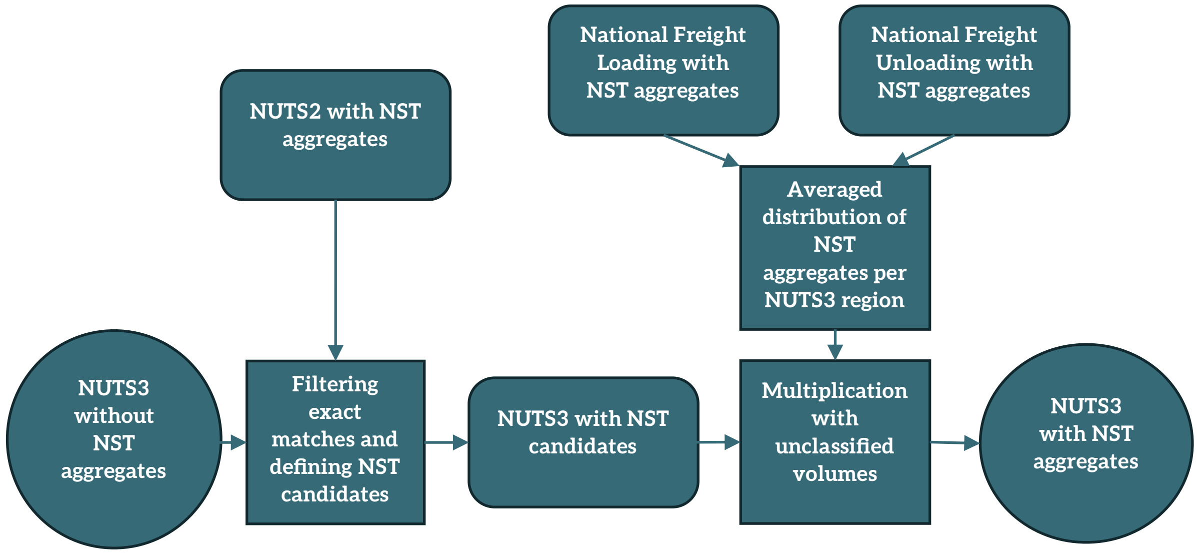

Figure 2-2: Visualization of the processing of the Dutch road transport data to obtain NST aggregates on NUTS3 level, source: own figure

2.3.2. INLAND WATERWAYS TRANSPORT

The aim of the analysis regarding waterborne transport was the comparison with road transport in terms of the kind and volume of transported commodities, as well as with respect to the transport activities in tkm.

For the comparison, the data was filtered to origin-destination pairs from, to and within the Netherlands, as well as to origin-destination pairs from, to and within Belgium, in the year 2022. Moreover, the classification of goods was accumulated according to the NST aggregates of the road data. Since no data was available on a NUTS3 level, the analysis was constrained to a NUTS2 level. The derivation of transport infrastructure networks or the calculation of tkm is described in the subsequent section.

Transport Infrastructure Networks

Under the simplified and theoretical assumption that cargo transports will typically strive to use the shortest path between origin and destination, a network graph of the European road network can be used to solve shortest path problems for each origin-destination pair in order to approximate effective distances and therefore calculate an estimation of ton-kilometers on any given link.

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To ensure compatibility, the same methodology is applied to IWW using a river network, through EuRIS' API.

The resulting routing data serves as the foundation for the calculation of ton-kilometers (tkm), where the length of trip through their respective networks forms the basis of calculations in both cases. Consequently, the resulting values can be directly compared in the later analysis.

The analysis was conducted using Python.

2.3.3. ROAD NETWORK

Road data is on the NUTS3 level, and therefore has many more individual connections compared to NUTS2 aggregated data (cf. 2.4). For road, there is no API like EuRIS for IWW, which would facilitate the amount of necessary shortest-path calculations without incurring substantial costs. To remedy this, a routable network of all motorways, highways and their primary road links in continental Europe was created to perform the required calculations locally. To achieve this, available geodata on primary road networks was obtained from OpenStreetMaps Overpass API for the Netherlands and Belgium as well as for all relevant countries with recorded transports to or from Belgium and the Netherlands. These primary network graphs were then preprocessed and combined. Subsequently, several algorithms were developed and applied to fix faulty connections and to simplify the structure of the network. Finally, checks were performed to analyze whether all secondary data needed for routing (segment length, speed limit for trucks) were available for all edges. Where there were such gaps in the data, the missing information was either measured (e.g. segment length), derived from similar road segments or individually researched (e.g. national speed limits for trucks).

Initially, the combined network comprised close to 93.000 strongly connected components as part of a single, very large weakly connected component. A component (i.e. a part of the network) is strongly connected in a network sense if any point in the component can be reached from any other point within the same component. While this initial network was therefore extremely fragmented, the final network graph after processing consists of a single strongly connected component and no weakly connected components.

This resulting network spans from Spain to the outskirts of Russia - effectively allowing routing calculations throughout continental Europe. Notably, only primary highways and their linking roads were included in the network, to reduce the risk of conveying a false sense of precision.

To prepare for the shortest path calculations, representative centroids had to be defined for each NUTS3 region, to act as start and endpoints of the given routes. To that end, the principle of closeness centrality was applied to identify representative nodes. This measure of centrality was used to find nodes in a network with the shortest average distance to all other nodes, which, in the case of a road network, translates to the most centrally located or most accessible highway junction in the respective area.

Finally, using these representative points, shortest paths in Europe's highway network were calculated for each origin-destination-pair found in the road transport matrix using an implementation of the Dijkstra shortest path algorithm. A validation exercise where routing results of 50 random samples were compared to that of Googles routing API showed only minimal deviations, which can be explained by Google using real time information on traffic density and roadworks in their routing.

Using this data, the distance covered by truck was assessed for each OD-Pair and approximate tkm were calculated.

The indicated cargo volumes for each resulting route were then allocated to their respectively used road segments in the network graph, to allow for aggregated analysis on the network level, as well as for visualization.

2.3.4. IWW INFRASTRUCTURE NETWORK

To facilitate this analysis for IWW data, the EuRIS API was used to calculate shortest paths between given origin destination pairs. To find representative points to act as start and endpoints for routing, the river network for each NUTS2 region was examined and the largest port on the largest river (based on CEMT Class) was chosen and passed to the EuRIS API for shortest path calculation. If there was no possible connection using these points for any origin-destination pair (because the chosen rivers were simply not connected), the largest port of the next largest river was iteratively chosen until a possible connection was found.

The result of the API calls is a sequence of river segments used for a given origin-destination-pair, and their associated geometries in geojson format.

The volumes transported on these segments were cumulatively added to their respective river sections in the network. The result is a shapefile, as well as a GeoPackage with the geographical data of the European rivers and the volumes per NST category estimated to be transported on each river segment. Given the lengths of these segments and their transport volumes, tkm were calculated for the inland waterway transport for each origin-destination-pair as well as their respective aggregations.

2.4 DESCRIPTIVE ANALYSIS OF THE DATA

In the following sections patterns and key findings from the analysis of the data are presented. For the Netherlands, origin-destination pairs (OD-Pairs) were considered throughout the analysis. In the obtained Dutch road data, 12176 pairs were reported on NUTS3 level and 2366 were reported on NUTS2 level. For direct comparison with IWW data, the analysis considered the NUTS2 data points. In the obtained Dutch IWW data 971 OD-Pairs were reported on NUTS2 level.

For Belgium, transported volumes of goods were considered. The Belgian road data includes volumes reported in 43 out of 51 NUTS3 regions in Belgium. For IWW 653 OD-Pairs were reported on NUTS2 level.

In the analysis three different quantities are discussed:

- The relative shares of goods per mode of transport.
- The absolute volume transported per NST aggregate and mode of transport.
- The total tkm per NST aggregate and mode of transport.

The shares, as well as the absolute volumes are based on the data obtained from CBS and Eurostat. The tkm were calculated based on the transport networks, as described in 2.2.5. The OD-Pairs then became routes within the network.

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For Belgium, only the relative shares of goods per mode of transport are presented, since the obtained data proved insufficient for a further analysis. Moreover, a direct comparison between road and IWW data was not possible, thus only the Dutch data is considered in Sections 2.4.3., 2.4.4 and 2.4.5 of the analysis.

In the description of the share of NST aggregates four different cases are distinguished.

- Case 1: All OD-Pairs.
- Case 2: Mode-Choice OD-Pairs, i.e. OD-Pairs that appear in both the road and the IWW data, suggesting that shippers, in principle, have the choice between using the road and inland vessel.
- Case 3: All Regional OD-Pairs, i.e. OD-Pairs going to or coming from the specific regions relevant for the case studies of AUTOFLEX as defined in 2.2 .
- Case 4: Regional Mode-Choice OD-Pairs, i.e. OD-Pairs going to or coming from the specific regions relevant for the case studies of AUTOFLEX as defined in 2.2 .

By looking at *All OD-Pairs* general patterns can be examined. Considering *Mode-Choice OD-Pairs* additionally, allows for a first estimation of potential goods to be shifted from road onto IWW since in principle a choice between the two modes of transport is given. The regions relevant for the AUTOFLEX use cases are the regions around the cities of Rotterdam, The Hague, Utrecht, and Amsterdam in the Netherlands and the areas surrounding Rotterdam, Antwerp, and Ghent in Belgium.

2.4.1. ROAD TRANSPORT

The Netherlands – Dutch registered vehicles

The total reported volume of goods transported on trucks registered in the Netherlands in 2022 amounts to 666 million t. Figure 2-3: gives an overview of the total volumes per NST aggregates transported on roads over *all reported OD-Pairs*. The three highest shares of the total transported volume are "Agricultural products", "Building materials" and "Miscellaneous". They make up more than 70 % of all transported goods. The remaining five aggregate each amount to below 10 %.

The described shares of case 1 are almost identical in the other three cases. As indicated in Figure 2-4, the shares in the *Regional OD-Pairs*, in the *Mode-Choice OD-Pairs* and in the *Regional Mode-Choice OD-Pairs* show no significant deviation from those of *All OD-Pairs*. Comparable shares of each NST aggregate are transported in all four cases. It suggests that the availability of IWW has almost no effect on the composition of the transported NST groups in competing transport modes. It underlines the broad availability and wide use of truck transport. However, it needs to be noted that some of the perceived stability in the relative shares could be due to the high-level grouping to NST aggregates, which is likely to mask some of the finer differences in commodity shares.

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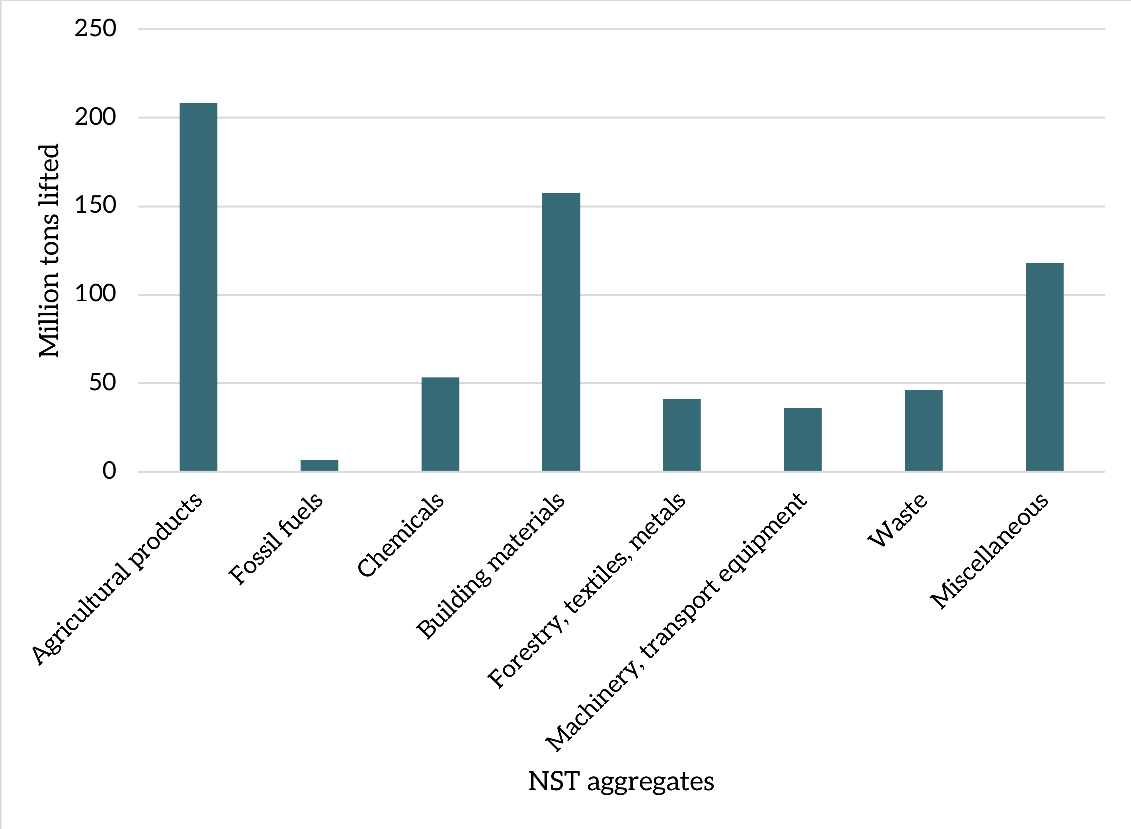

Figure 2-3: Million tons lifted per NST aggregate of *All OD-Pairs* of Dutch registered trucks for the transport of the Netherlands 2022, source: CBS

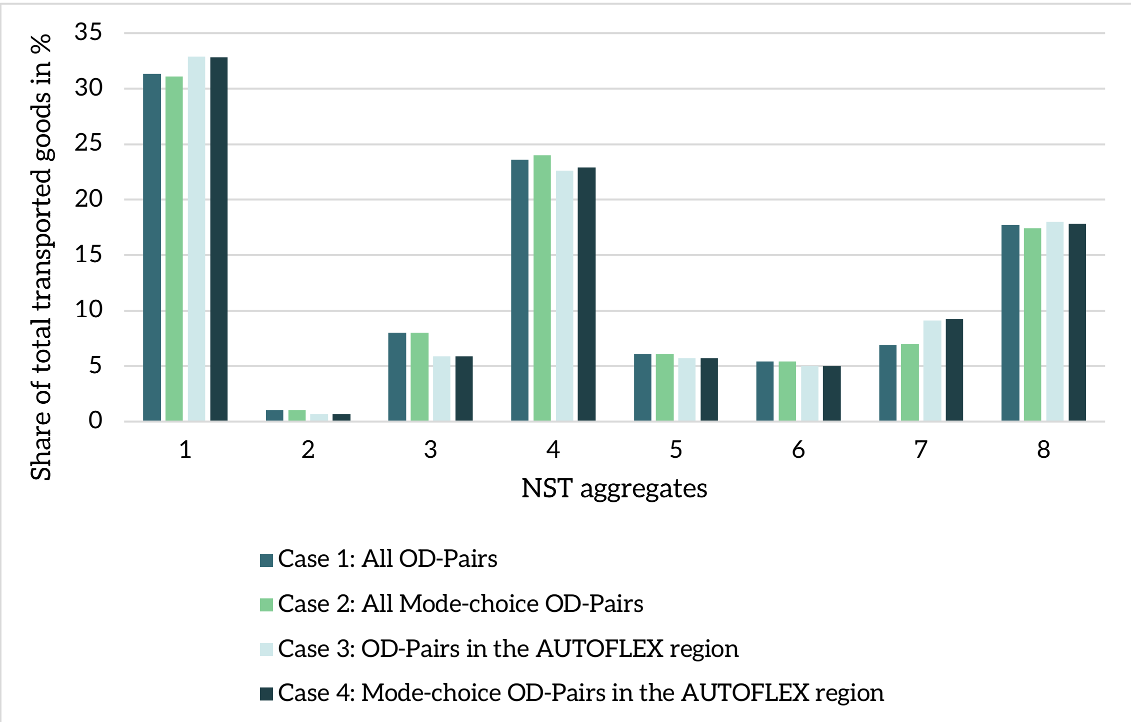

Figure 2-4: Comparison of NST aggregate shares in % for different types of OD-Pairs of Dutch registered trucks of the transport of the Netherlands 2022, source: own deduction from CBS and Eurostat data

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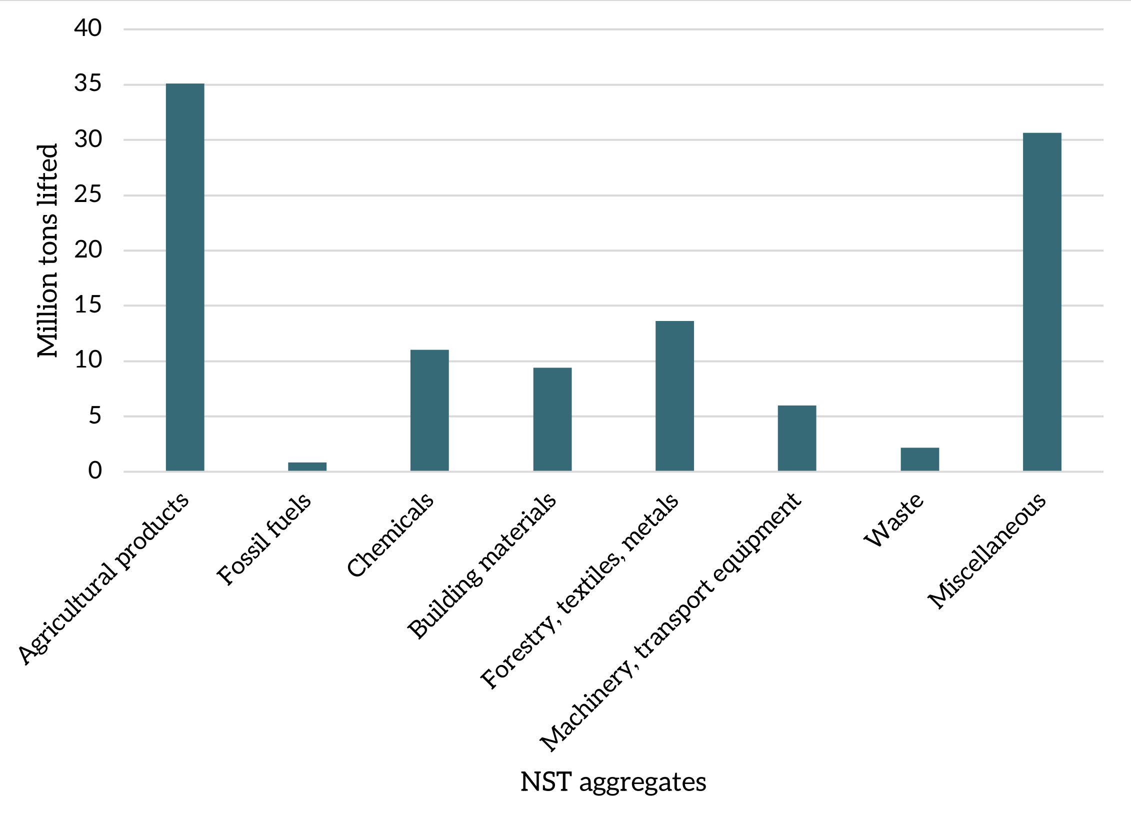

Figure 2-5: Million tons lifted per NST aggregate of All OD-Pairs of foreign registered trucks for the transport of the Netherlands 2022, source: CBS

The Netherlands – Foreign registered vehicles

The total volume transported on vehicles registered outside of the Netherlands amounts to 108 million t. In contrast to the goods on Dutch registered vehicles, only two NST aggregates show significantly bigger shares than the other six aggregates: “Agricultural products” and “Miscellaneous”. Both previous figures illustrate the difference in the share of the aggregate “Building materials” compared to Dutch registered vehicles corresponds to general patterns in the transport by foreign trucks, i.e. cabotage.

Cabotage in the Netherlands, governed by EU regulations, allows foreign carriers to perform domestic transport operations under specific conditions. This practice enhances the efficiency of the transport sector by reducing empty runs and optimizing transport capacity utilization. However, it also introduces competition from foreign carriers, which can impact the distribution of transported goods. The prevalence of "Agricultural products" and "Miscellaneous" in foreign-registered vehicles indicates the profitability and competitiveness of these carriers in the Dutch market.

Generally, in the transport of foreign-registered vehicles, patterns analogous to those in the transport of Dutch-registered vehicles can be found: a wide array of different commodities is being transported, supporting the suitability and availability of trucks for various transport operations. The cabotage operations contribute to this diversity by allowing foreign carriers to compete in the Dutch market, ensuring that different types of goods can

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be efficiently transported within the country. This underscores the importance of a robust and flexible transport system that can cater to the diverse needs of the market, facilitated by both domestic and foreign carriers.

Generally, in the transport of foreign registered vehicles, patterns analogous to those in the transport of Dutch registered vehicles can be found: A wide array of different commodities is being transported, which supports the suitability and availability of trucks for different transport operations.

Belgium

For Belgium the total reported volume of loaded and unloaded goods in 2022, as recorded by Eurostat, amounts to 444 million t. Similarly to the Netherlands, the biggest share of cargo can be attributed to the NST aggregates "Agricultural products", "Building materials" and "Miscellaneous". Since no OD-Pairs are available for the transport of Belgium, a comparison to mode-choice OD-Pairs cannot be performed. The regions relevant for AUTOFLEX are presented below. They follow the same allocation of volume per NST aggregate as the total volume.

Again, the make-up of commodity groups in road cargo flows does not seem to be determined by a specific regional context but represents general cargo flows.

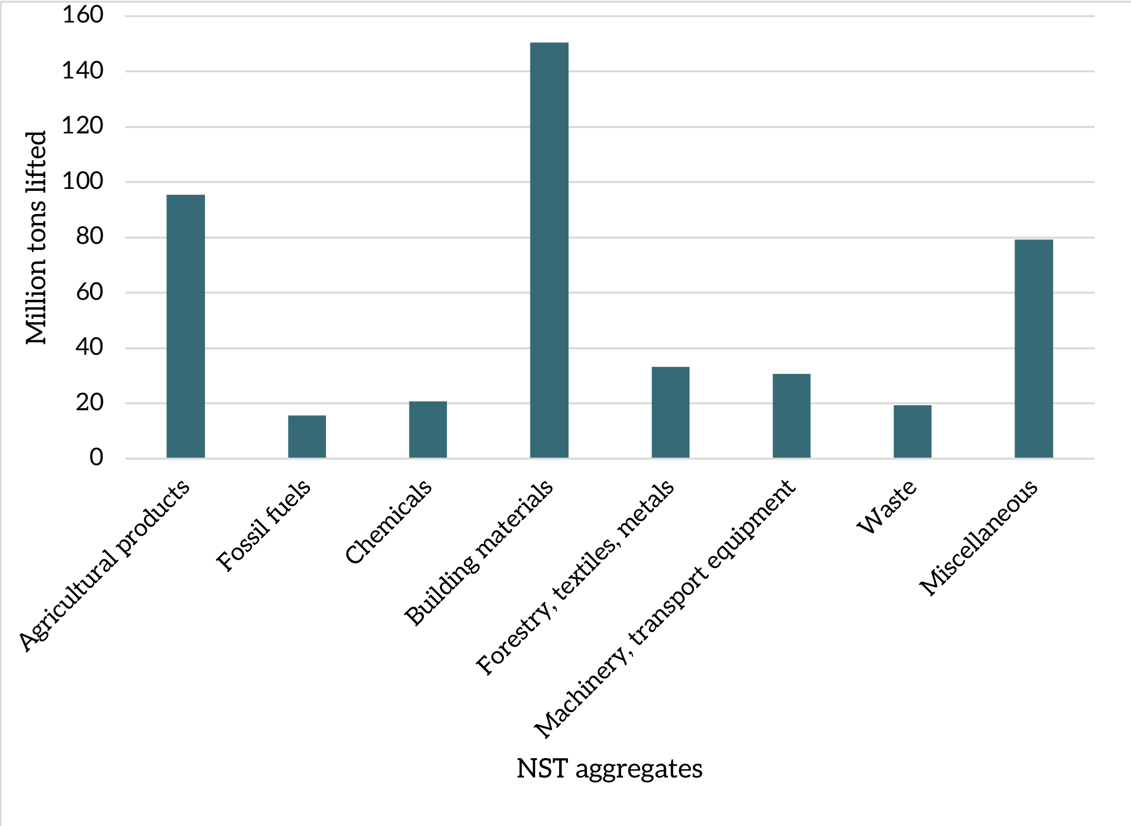

Figure 2-6: Million tons lifted per NST aggregate on Belgian registered trucks for the transport of Belgium 2022, source: Eurostat

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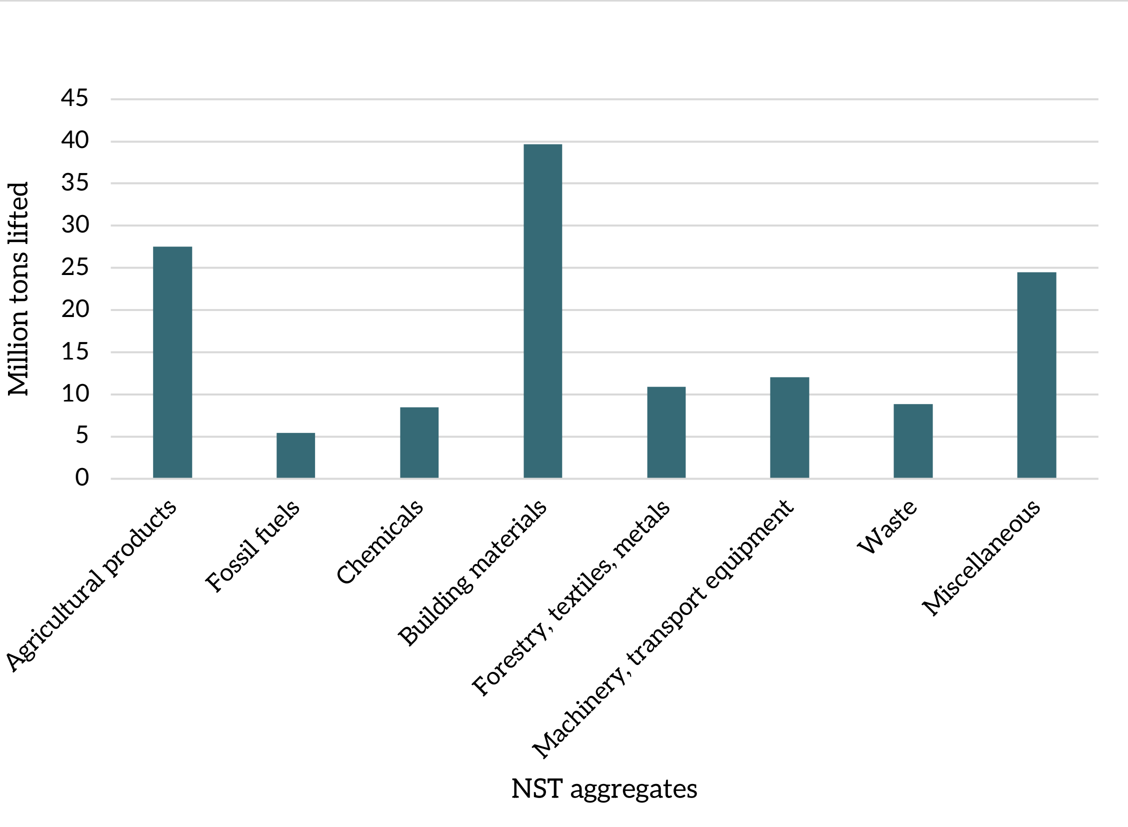

Figure 2-7: Million tons lifted per NST aggregate on Belgian registered trucks for the transport of Belgium in the AUTOFLEX region 2022, source: Eurostat

2.4.2. INLAND WATERWAYS TRANSPORT

The Netherlands

The total reported volume of goods on IWW in 2022 for the transport of the Netherlands amounts to 356 million t. Figure 2-8: shows the total volume per NST aggregate for *All OD-Pairs*. On all OD-Pairs, “Miscellaneous” marks the highest share of transported goods. . The next bigger shares are “Building materials”, “Fossil fuels”, and “Chemicals”. Together they amount to more than 80 % of the total transported goods on IWW.

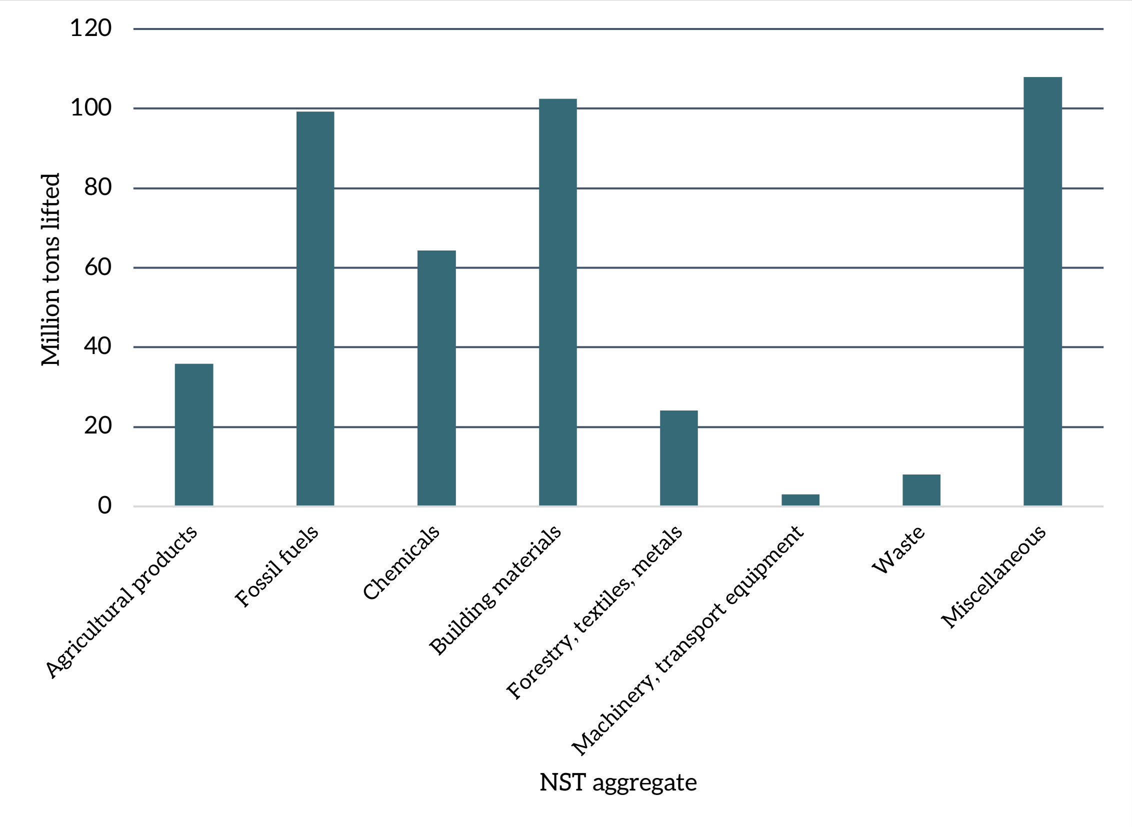

Figure 2-8: Million tons lifted per NST aggregate of *All OD-Pairs* on IWW for the transport of the Netherlands 2022, source own deduction from Eurostat data

Comparing the shares in the four distinguished cases for OD-Pairs, Figure 2-9: shows that the IWW shares remain similar over all of them. However, three aggregates show a difference of circa 5% per share between *All OD-Pairs* and the *Regional OD-Pairs*: “Fossil fuels” and “Miscellaneous” increase on regional OD-Pairs, while “Building materials” decreases.

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The increase of the two aggregates could hint at a higher handling of those types of goods in the AUTOFLEX region, and thus at a higher demand for inland waterway ships for those goods specifically. The use case regions include the port of Rotterdam, the biggest port of Europe and additionally the biggest oil port in North-West Europe. The impact of the port on the waterborne transport of the Netherlands is elaborated on in Section 2.4.6.

Similarly to the road transport, cargo flows on waterborne transport in the Netherlands do not appear to be influenced by the availability of road transport and the type of cargo being transported reflects the general suitability of waterborne transport for various commodities, ranging from liquid bulk, over break bulk to unitized cargo.

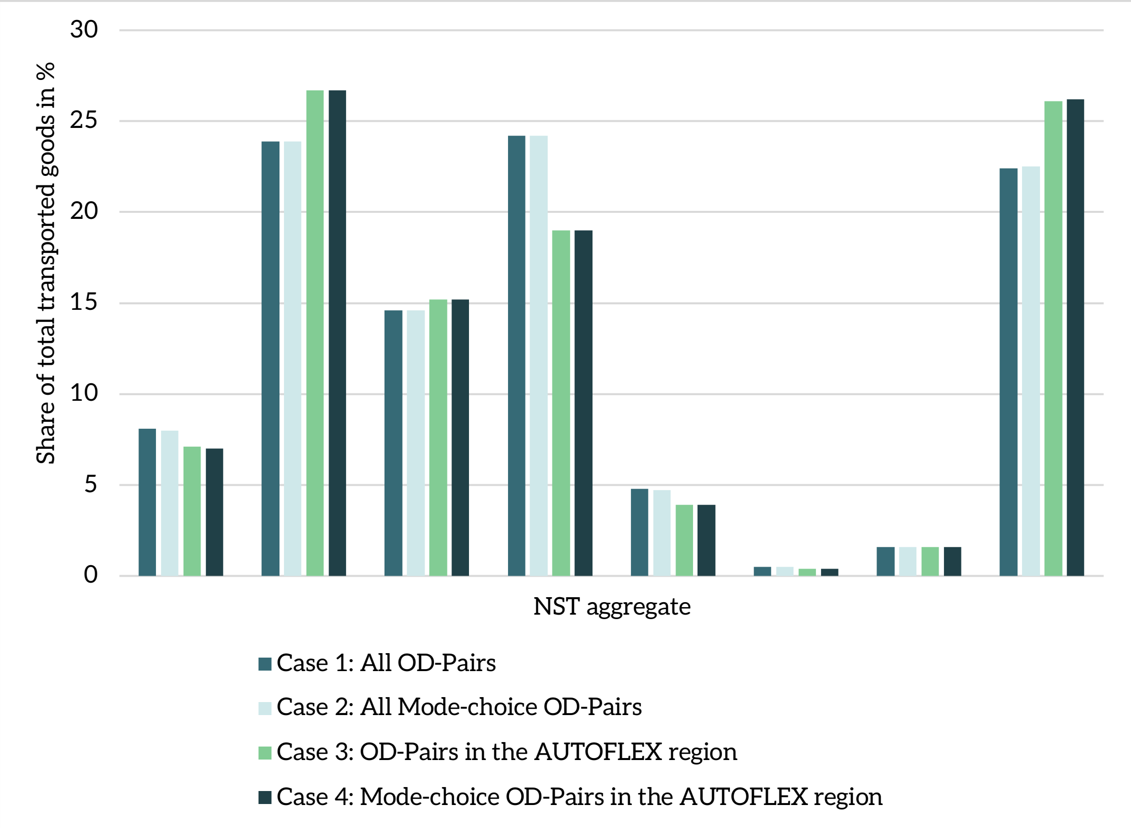

Figure 2-9: Comparison of NST aggregate shares in % of different types of OD-Pairs on IWW for the transport of the Netherlands for in 2022, source: own deduction from Eurostat data

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Belgium

The total reported volume of goods for the transport of Belgium on IWW in 2022 amounts to 216 million t. As seen in the figure below the highest NST aggregate share is

"Miscellaneous". The next bigger shares are "Fossil fuels", "Chemicals" and "Building materials". Belgium includes several major European ports, e.g. the port of Antwerp, which is a major driver of the high share of miscellaneous goods. The role of Antwerp for Belgian transport is illustrated in Section 2.4.6.

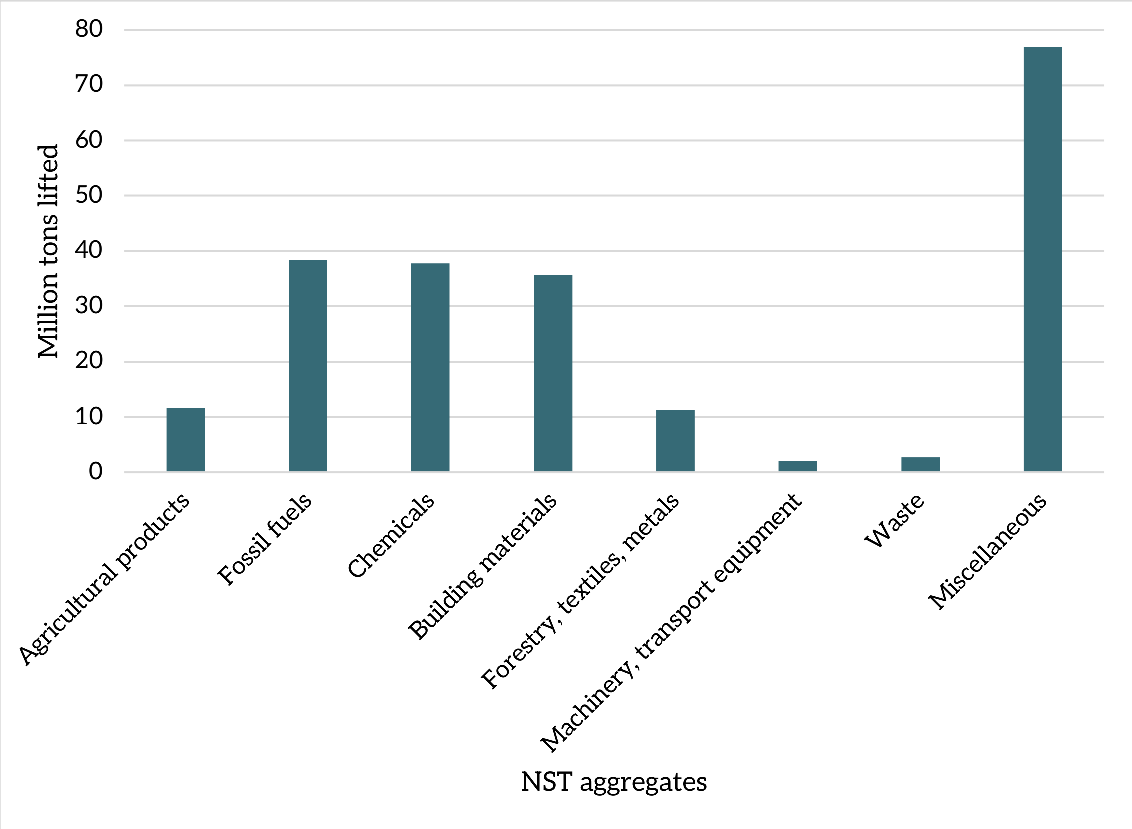

Figure 2-10: Million tons lifted per NST aggregate of All OD-Pairs on IWW for the transport of Belgium 2022, source own deduction from Eurostat data

The Belgian regions relevant for the AUTOFLEX use cases show a similar allocation of volumes compared to all regions. The total volume differs by 30 million t compared to All OD-Pairs; thus, a large part of Belgium's transport can be attributed to the Regional OD-Pairs. Since, Antwerp is part of the Regional OD-Pairs the high share of "Miscellaneous", can be traced to the impact of the port on Belgium's transport which is elaborated on in chapter 2.4.7. The allocation of volumes in the AUTOFLEX regions is visualized below

Belgian waterborne transport highlights, like the Dutch waterborne transport, the suitability of inland water ships for a wide range of cargo groups.

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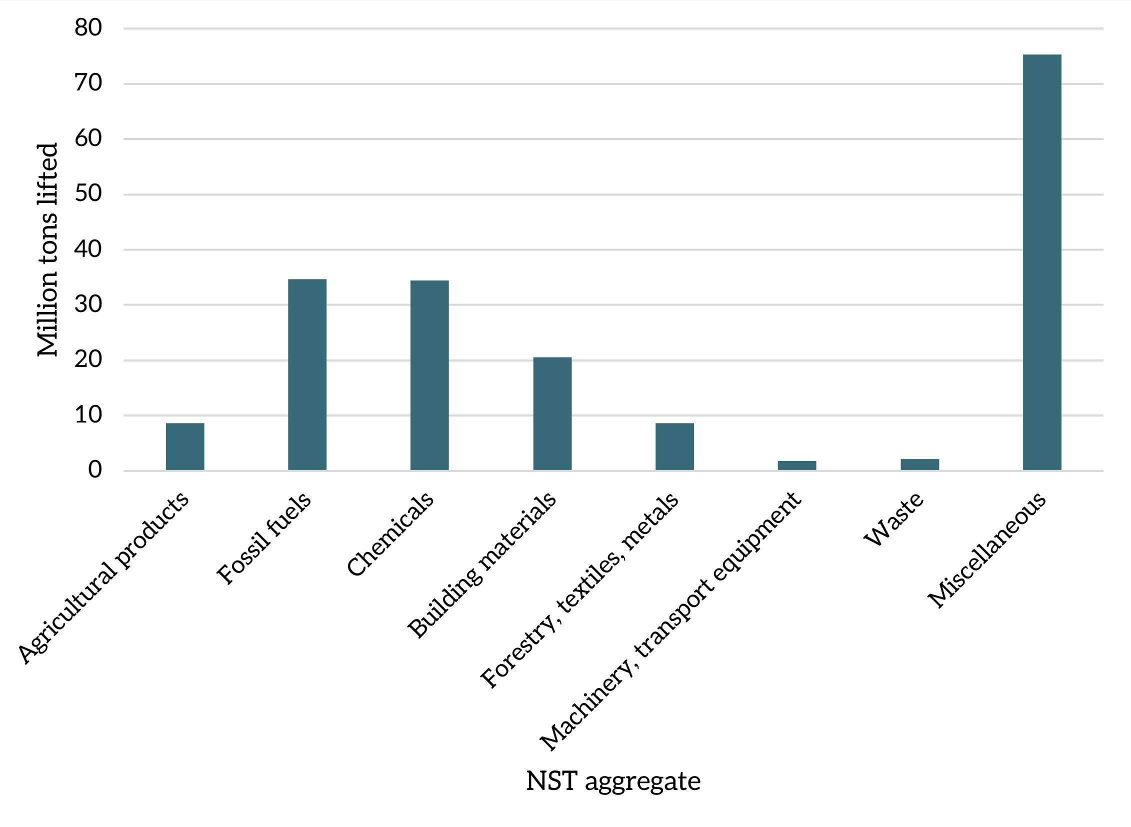

Figure 2-11: Million tons lifted per NST aggregate of *Regional OD-Pairs* on IWW for the transport of Belgium 2022, source own deduction from Eurostat data

2.4.3. COMPARISON OF SHARES OF GOODS

As elaborated on in chapter 2.4 , all comparisons discussed in this chapter, as well as in chapters 2.4.4 and 2.4.5, are restricted to the Netherlands. In this chapter, differences between the shares of goods per mode of transport are discussed.

Examining *All OD-Pairs*, the aggregate "Agricultural products" shows the largest difference between roads and IWW. The aggregates that are most similar for roads and IWW are "Building materials" and "Forestry, textiles, metals". "Miscellaneous" has a high share for both modes of transport. These patterns are coherent with the general characteristics of the two different modes of transport. "Agricultural products" are often perishable goods that require short transportation time and thus are more often transported by truck. IWW is more suitable for bulk cargo which includes "Building materials" and "Forestry, textiles, metals".

The relation between the two modes of transport does not change when comparing *All OD-Pairs* and *Mode-Choice OD-Pairs* but a deviation is visible when comparing *All OD-Pairs* to the *Regional OD-Pairs*.

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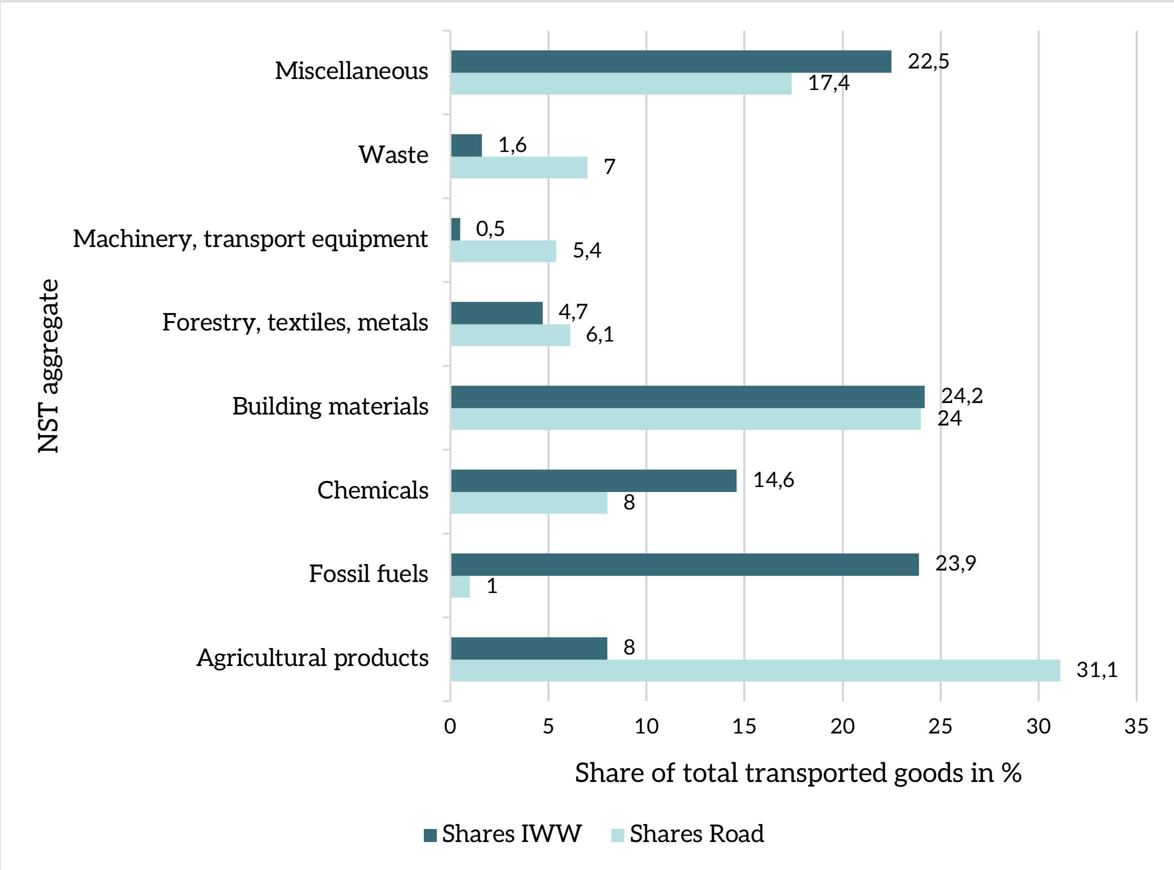

Figure 2-12: Comparison of NST aggregate shares in % on road and IWW of *Mode-Choice OD-Pairs* for the transport of the Netherlands 2022, source: own deductions from CBS and Eurostat

Regarding the *Regional OD-Pairs*, the relative differences between road and IWW for the NST aggregates “Miscellaneous”, “Building materials” and “Fossil fuels” each deviate by about 5 %. This is due to changing shares of NST aggregates of IWW transport in the regional contexts. As discussed in 2.4.2, the shares of goods transported on IWW, show a different NST aggregate allocation of volumes on *Regional OD-Pairs* compared to on *All OD-Pairs*, while the relative distribution of NST aggregates of road transport remains consistent over all examined OD-Pairs and subsets thereof. Consequently, the relative changes in the comparisons between the two transport modes over the different OD-Pair configurations are exclusively due to the regionally changing NST aggregate allocation of IWW.

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Figure 2-13: Comparison of NST aggregate shares in % on road and IWW of *Regional Mode-Choice OD-Pairs* for the transport of the Netherlands 2022, source: own deductions from CBS and Eurostat

Overall, it can be noted that several types of goods are found to be transported on both modes of transport. This indicates a demand for both modes of transport and the potential for modal shift over different types of goods.

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2.4.4. COMPARISON OF VOLUMES OF GOODS

For an understanding of the potential for a modal shift in absolute numbers, the total volume of transported goods on roads and IWW was compared additionally to the shares. As in the comparison of the shares, the obtained data for Belgium is insufficient for a meaningful analysis, thus the Netherlands are observed exclusively. Moreover, only vehicles registered in the Netherlands are considered. The total of transported goods on roads in the Netherlands in 2022 amounts to 666 million t. The total of transported goods on IWW in the Netherlands in 2022 amounts to 356 million t.

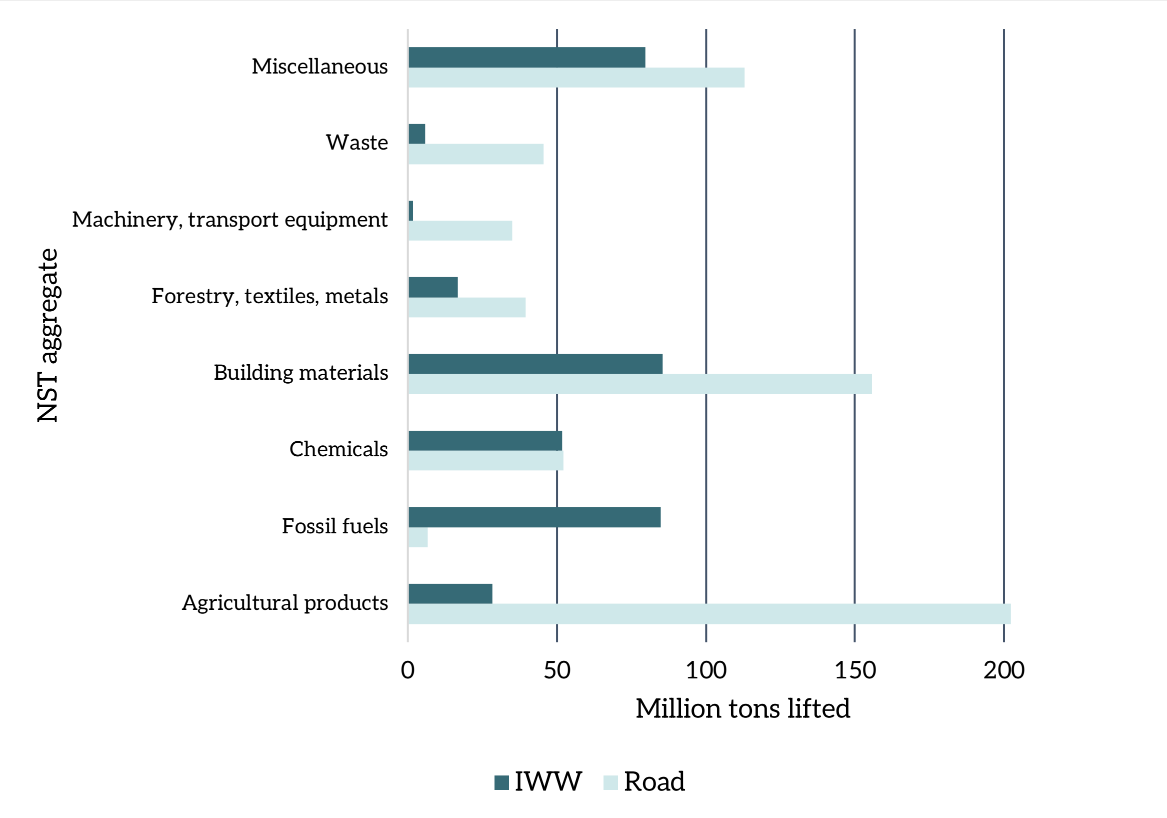

Figure 2-14: Comparison of million tons lifted per NST aggregate on road and IWW of *Mode-Choice OD-Pairs* for the transport of the Netherlands 2022, source: own deductions from CBS and Eurostat

Looking at *Regional OD-Pairs*, they show a different allocation of volumes than the allocation apparent over *All OD-Pairs*. This pattern matches the change in changes in the shares of cargo per mode of transport, discussed previously, which was visible when comparing *Regional OD-Pairs* against *All OD-Pairs.* While transport on roads makes up the bigger share on *All OD-Pairs*, in the AUTOFLEX region more goods of the aggregate are transported on IWW. Moreover, the difference between the transported volume of "Chemicals" nearly doubles within the region with a larger share being transported on IWW. Similarly, a larger share of "Building materials" is transported on IWW on *Regional OD-Pairs* and difference between road and IWW decreases.

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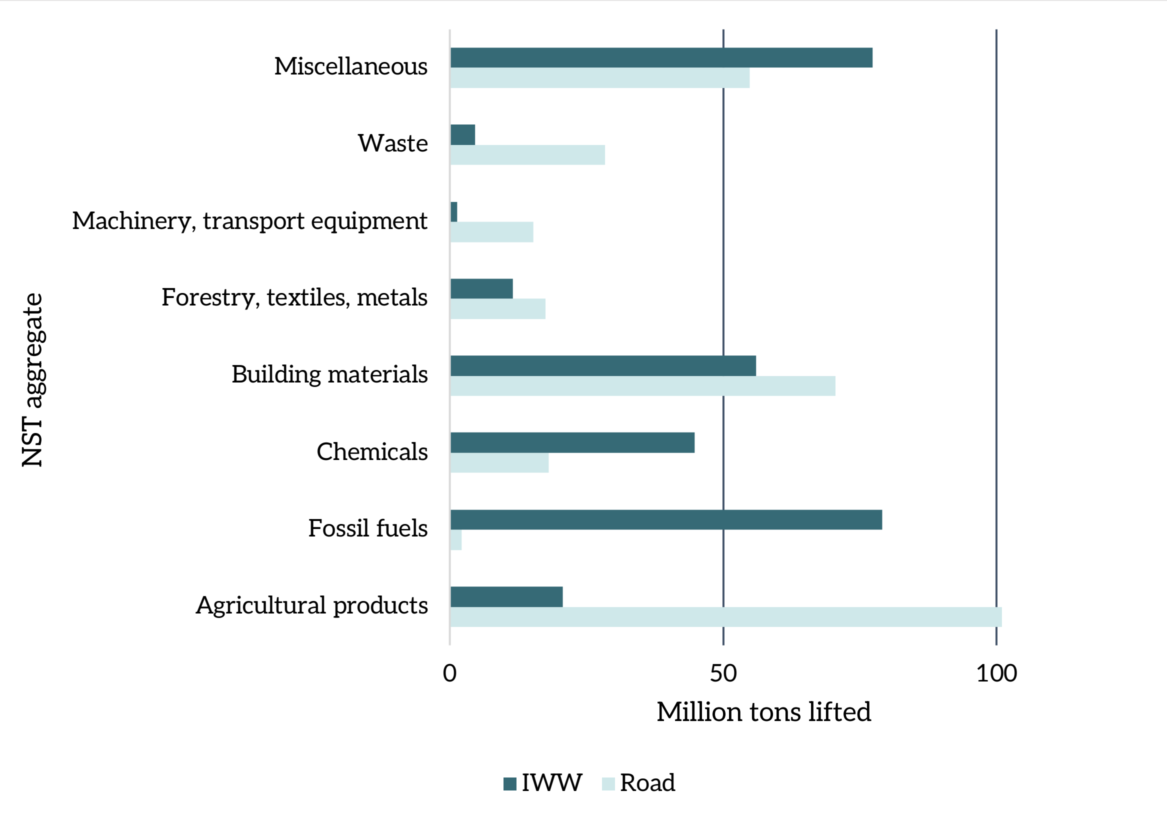

Figure 2-15: Comparison of million tons lifted per NST aggregate on road and IWW of *Regional Mode-Choice OD-Pairs* for the transport of the Netherlands 2022, source: own deductions from CBS and Eurostat8

The changed allocation of volumes on a regional level hints at a higher use of and therefore demand for IWW as a mode of transport in that region. Again, it should be noted that the AUTOFLEX region includes two major European ports, Rotterdam and Antwerp. They impact the total allocation of volume and the increase in cargo flows on IWW in the region. The role of the ports will be illustrated in Section 2.4.6.

Further, the comparison of total volumes highlights that several different types of goods are transported on both road and IWW and could potentially be shifted from one mode of transport to the other. IWW seems to be a much more flexible and adjustable transport mode to the requirements of market segments of the transport market, since no restriction to bulk or low value density goods can be identified.

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2.4.5. COMPARISON OF TON-KILOMETERS

Besides shares and total volumes, the sum of ton-kilometers (tkm) per NST aggregate on roads and IWW were compared. For the calculation of tkm the created transport networks were used, as described in 2.2.5.. Similarly to the total volumes, the tkm do not differ regarding *All OD-Pairs* compared against *Mode-Choice OD-Pairs*. But they do differ when it comes to *All OD-Pairs* and the *Regional OD-Pairs*. Exemplary, the allocation of tkm over the NST aggregates for all *Mode-Choice OD-Pairs* is visualized in Figure 2-16: The aggregates with the highest tkm on IWW are "Fossil fuels", "Building materials" and "Miscellaneous". On roads the largest aggregates are "Agricultural products" and "Building materials". For both modes of transport this coincides with their biggest aggregates of total transport volumes.

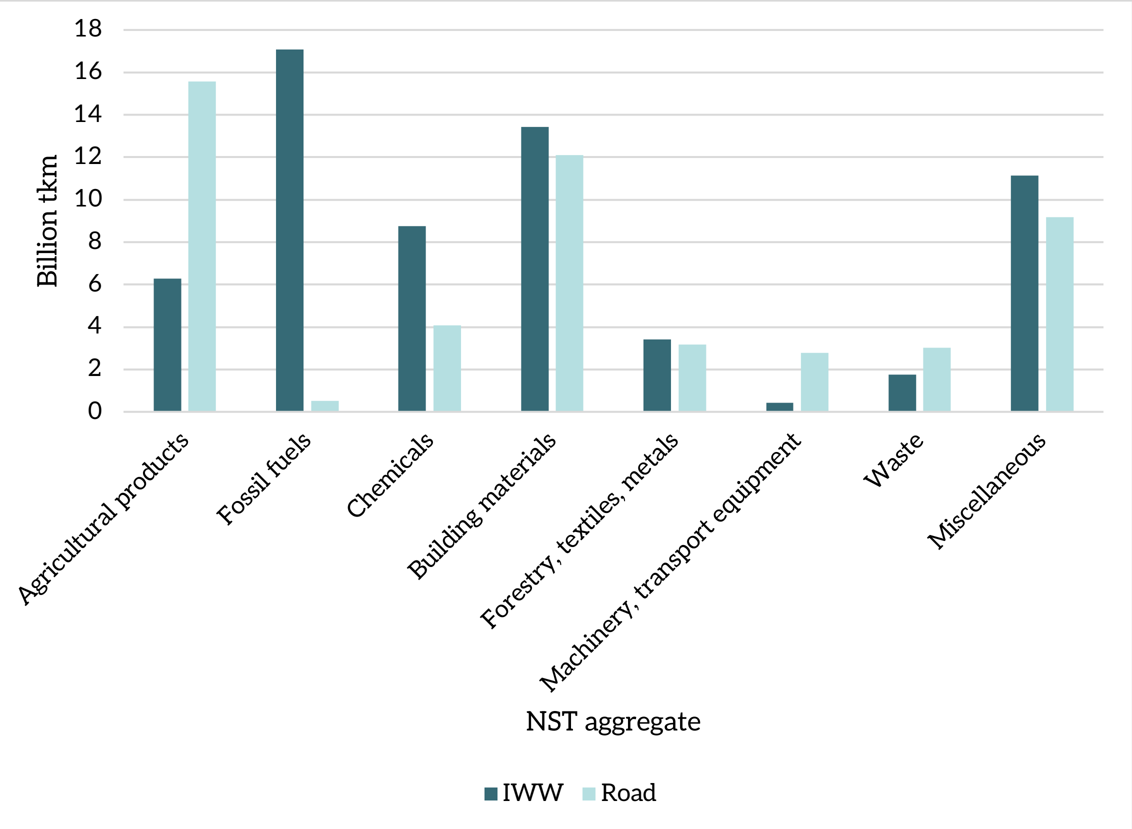

Figure 2-16: Comparison of tkm per NST aggregate on road and IWW of *Mode-Choice OD-Pairs* for the transport of the Netherlands in 2022, source: own calculations

The lowest categories are "Machinery, transport equipment" on IWW and "Fossil fuels" on roads., which also coincide with their total transported volumes. In contrast to the total volumes, the aggregates "Building materials" and "Miscellaneous" show a smaller difference between road and IWW in the allocation of tkm. This could be due to the fact that inland vessels are more suitable for weight constrained, i.e. high-density cargo, and thus are able to transport more tons on the same distance than trucks.

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Focusing on the *Regional Mode-Choice OD-Pairs*, biggest change is the increased difference between the tkm on road and IWW for "Miscellaneous". While the tkm of IWW on *Regional OD-Pairs* decrease by less than 1%, the tkm of road are half as big on *Regional OD-Pairs* as those on *All OD-Pairs*. This matches the pattern of total volumes, where the relation between road and IWW was flipped for *Regional OD-Pairs*, with IWW accounting for the bigger part. "Agricultural products" also changes when comparing *All OD-Pairs* and *Regional OD-Pairs*. IWW is reduced to two thirds of the tkm on *All OD-Pairs*, while road decreases by almost half of the tkm on *All OD-Pairs*. This could indicate that within the region of AUTOFLEX less agricultural products are harvested and transported.

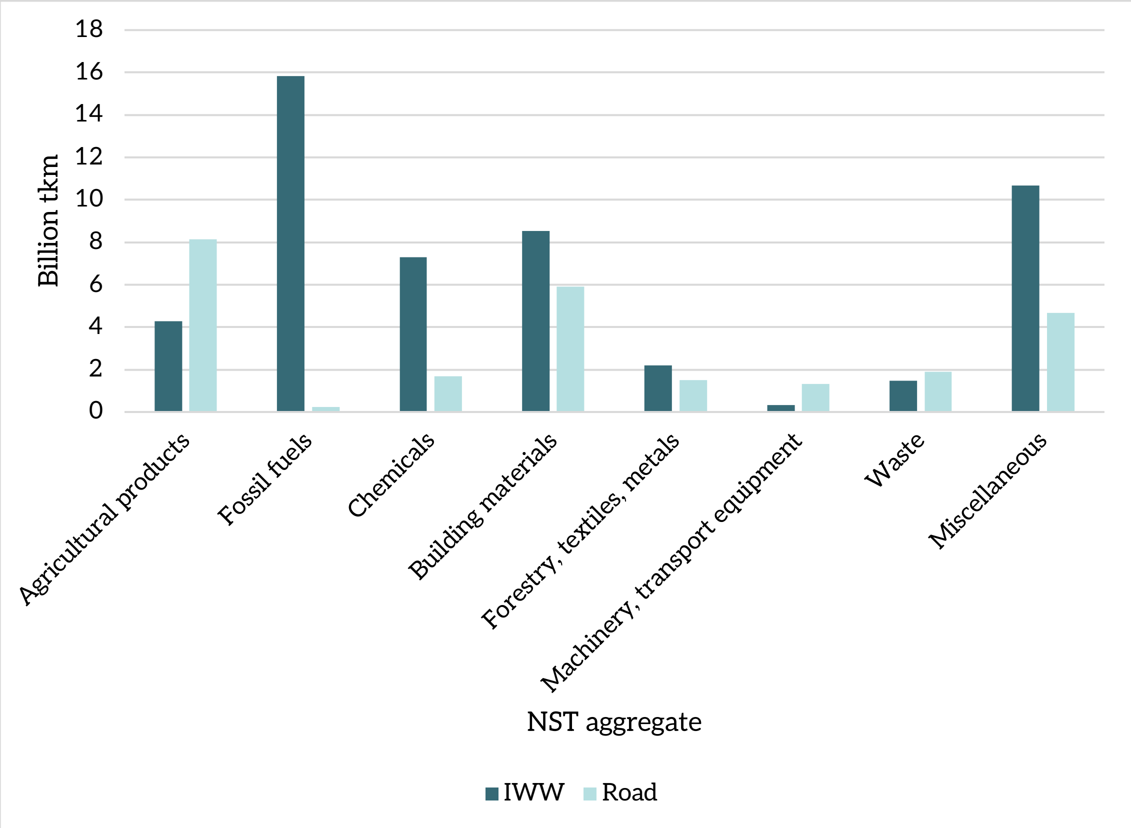

Figure 2-17: Comparison of tkm per NST aggregate on road and IWW of *Regional Mode-Choice OD-Pairs* for the transport of the Netherlands in 2022, source: own calculations

Generally, the comparison of tkm aligns with the previous comparisons of shares and total volumes. Road and IWW tkm are high regarding the types of cargo typically transported by each mode of transport. Moreover, the comparison underlines that several different types of cargo show potential for modal shift, since they are transported on both modes of transport.

In the course of the analysis of the Dutch data, the handled volume per NUTS2 region is compared against the CEMT river classes of the river segments passing through the cells. This is done by using the river network that was obtained as described in Section 2.2.5 and an aggregation of transported volumes per NUTS2 region. The biggest volumes occur in the NUTS2 cells that include the ports of Amsterdam and Rotterdam. These two NUTS2 cells contain river segments of CEMT VIa-VIc. Out of the remaining NUTS2 cells, five show similar volumes. All of them include river segments of at least CEMT Va or Vb. NUTS cells

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with the smallest volumes mostly enclose segments of CEMT two. This pattern indicates that higher river classes corelate with higher volumes being handled in the corresponding NUTS2 regions. An in-depth analysis of the river network is to be found in Deliverable 2.1.

2.4.6. THE IMPACT OF PORTS

The Netherlands and Belgium include two major European ports: Rotterdam in the Netherlands, the largest port of Europe, both for containers and oil and gas. Antwerp in Belgium, is the second largest port of Europe. To understand their impact on the transport distribution in Belgium and the Netherlands, the IWW and road data were filtered to exclude the NUTS regions containing the ports. For the Netherlands, the NUTS2 region “NL33”, South-Holland, was excluded. For Belgium, “BE21”, the province of Antwerp, was excluded. It has to be noted, that the attribution of the volumes of the respective NUTS2 regions to the ports is lacking granularity, since the NUTS2 regions include more than the port’s areas. However, the NUTS2 regions make up roughly half of each country’s transport work, which originates to a large extend from the ports.

For road transport the relative allocation of volume per NST aggregate remained the same, with only the total volume decreasing by 184 million t in the case of excluding Rotterdam and by 7 million t in the case of excluding Antwerp. Contrastingly, the allocation of volume of IWW transport seemed to be impacted by the ports.

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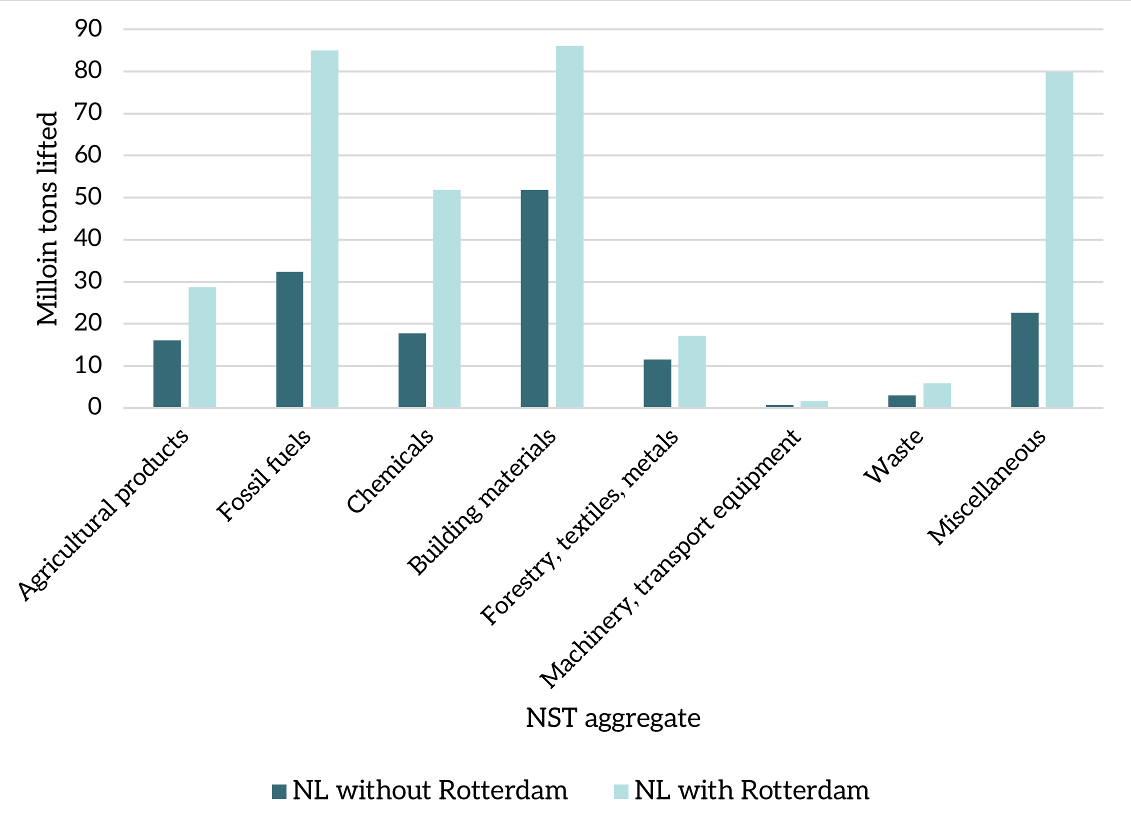

Figure 2-18: Comparison of million tons lifted of *All OD-Pairs* on IWW for the transport of the Netherlands including and excluding the region of Rotterdam 2022, source: Eurostat

Firstly, looking at the impact of Rotterdam onto the total volumes of cargo on IWW in the Netherlands, it shows that Rotterdam's transport makes up two thirds of the total volume of "Miscellaneous" and more than half of the volume of "Fossil fuels". Figure 2-18: depicts the comparison of Dutch transport including and excluding Rotterdam. In total Rotterdam's transport makes up 56 % of the transport of the Netherlands. Rotterdam is included in the AUTOFLEX region. Thus, the large volumes of "Miscellaneous" and "Fossil Fuels" coming from Rotterdam's transport, explain the increase of IWW volumes in relation to road volumes on *Regional OD-Pairs*, which became apparent in Section 2.4.4.

The impact of Rotterdam can further be observed in the comparison of the tkm for IWW and road in Section 2.4.5. When excluding Rotterdam, the total tkm of both transport modes combined have decreased by around 50 billion tkm compared to the case of including Rotterdam. Moreover, the relation between road and IWW for the NST aggregates "Chemicals" and "Miscellaneous" changed, with the tkm of IWW being reduced by half while road tkm are only decreasing by around 20 %. Similarly, the tkm of "Fossil fuels" on IWW including Rotterdam, make up half of the total tkm. This further highlights the impact of Rotterdam's transport onto the transport on *Regional OD-Pairs*, specifically regarding IWW transport.

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The impact of Antwerp onto the IWW transport of Belgium is illustrated in Figure 2-19:. The transport of Antwerp makes up three-quarters of “Miscellaneous” of Belgium’s transport volumes. Other big shares that Antwerp is contributing to are “Fossil fuels”, “Chemicals”, and “Building Materials”. Overall, Antwerp’s transport volume makes up 65 % of Belgium’s’ total transport volume. This underlines the ports’ important role for IWW transport of Belgium. Antwerp is also included in the AUTOFLEX region, which explains the high share of “Miscellaneous” visible on *Regional OD-Pairs* in Belgium as seen in Section 2.4.2.

Both Rotterdam and Antwerp influence the transport of the Netherlands and Belgium respectively.

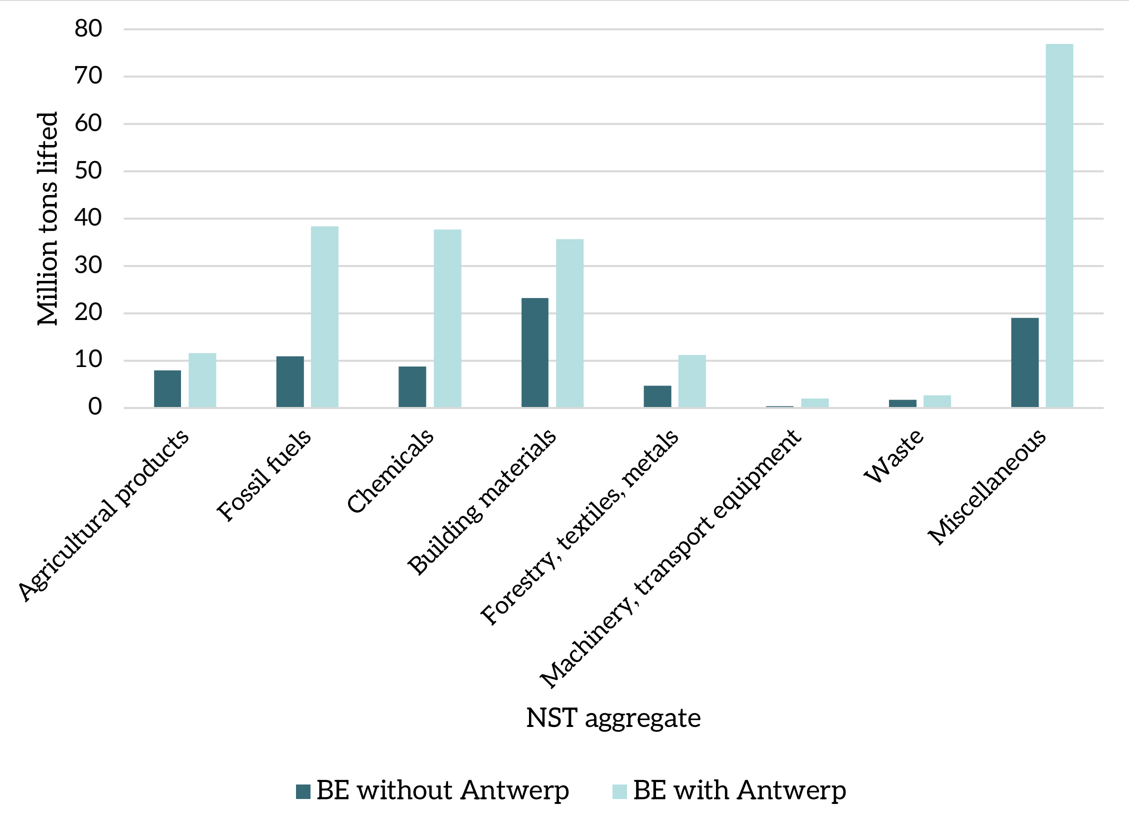

Figure 2-19: Comparison of million tons lifted of *All OD-Pairs* on IWW for the transport of Belgium including and excluding the region of Antwerp 2022, source: Eurostat

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2.4.7. CONCLUSION

Two general patterns that are significant for the further work in the AUTOFLEX project can be observed in the data:

- Several different types of goods are transported on both modes of transport, neither does any single commodity nor one transport mode stand out.
- "Miscellaneous" makes up a high share on both modes of transport.

These two patterns imply that a modal shift potential is given for several types of commodities. The modal shift could be feasible in the region of the AUTOFLEX use cases but also outside of those regions. "Miscellaneous" includes containerized cargo, which generally have a high potential for modal shift due to their efficient handling characteristics. Thus, they have to be considered as potential.

The data does not support an identification of a commodity that is better suited for either IWW or road transport. From the data that can be obtained no clear advice can be provided which load units stand for more potential for a IWW service, stackable units like container would mean LoLo operations while road units like semi-trailers would allow RoRo operations.

Instead, it suggests that this is a supply-driven market where mode choice seems dependent on induced demand. This means it is important to support the development of diverse transport offerings, as the key factor for mode choice appears to be the availability of a competitive connection. Factors such as the value of time and breaks in the transport chain play a significant role and can be exclusion criteria for water transport, but these seem to be exceptions rather than the rule.

In summary, the data highlights the importance of fostering a variety of transport options to maintain a competitive and flexible market. The ongoing AUTOFLEX project can leverage these insights to facilitate effective modal shifts, improve transport efficiency, and meet the varied demands of the market. Further analysis will build upon these findings, integrating them with broader research to develop comprehensive strategies for facilitating a modal shift towards IWW transport.

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3 MODE SELECTION CRITERIA

3.1 CHARACTERISTICS OF ROAD AND IWW TRANSPORT

The two modes of transport discussed in the descriptive analysis of the data were road transport and IWW transport. The analysis has shown that both modes of transport seem to be suitable for a range of commodities. For a better understanding of the suitability of the two modes of transport and the preferability of one over the other, their respective characteristics will be briefly introduced.

Road transport is characterised by the following aspects:

- Short transportation time
- An extensive road network that allows access to most locations
- High flexibility in term of loading and unloading goods, allowing for door-to-door and first and last mile transportation
- Availability of a variety of commodity-specific vehicles
- Typically, capacity constrained by volume (low density goods)
- Higher operating costs compared to IWW transport, mainly due to fuel
- High emissions, e.g. CO_2 emissions and particulate matter emissions, as well as noise pollution
- Higher accident rate, compared to IWW transport

IWW transport is characterised by the following aspects:

- High weight efficiency (high density goods)
- Lower operating costs compared to road transport
- High mass output, resulting from high mass capacity and low costs combined with transport over long distances
- Low emissions and little noise pollution (depending on the propulsion system)
- Lower accident rate, compared to road transport
- Long transportation time
- Network is limited to navigable waterways
- Low flexibility in terms of loading and unloading goods, additional handling equipment is required

Overall, transport by truck is more flexible and faster than transport by inland waterway vessel. With the latter having a higher mass output and requiring less energy per transported unit than the transport by truck. The listed characteristics influence the choice for a mode of transport. The subsequent section discussed how the characteristics are weighted, and which models of decision-making are typically employed.

3.2 MODE CHOICE

To understand and possibly forecast the choice of transport operators regarding their route and modal choice considerations, numerous multi-criteria systems for mode choice have been developed in transport research.

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Meixell 2008 describes that historically practitioners first decided for a transport mode like road, rail, waterway or air and thereafter selected the appropriate carrier type within that mode. But with the emergence of innovative manufacturing strategies like JIT and a wider array of transportation solutions, the mode selection problem has become less linear, including multiple variables and objectives (Engebrethsen 2018; Meixell 2008). In recent times, the dominant perspective gradually changed from a competitive view on transport modes towards combining them for the most cost-, distance- and time-efficient solutions, alleviating the appeal of intermodal transport (Beresford 2021). Whether one considers single-mode transport or the links of an intermodal transport chain, the question which mode is the most appropriate for a specific transportation task remains relevant. Nevertheless, it is necessary to clarify that these modal choice decisions are often made with incomplete knowledge of the transport mode characteristics or the availability of transport mode alternatives (Mommens 2020).

3.2.1. COSTS FACTORS

The most thoroughly researched criteria utilized for this decision process can be split into two categories: cost and quality factors. The cost category can be further differentiated into transport, investment and transshipment costs. Regarding transport costs themselves, Beresford 2021 presents a simple trade-of heuristic that summarizes conventional, cost-focused modal decision making since the 1980s. The heuristic results from combining the five cost drivers distance, value, volume, urgency and weight into six different trade-of relationships:

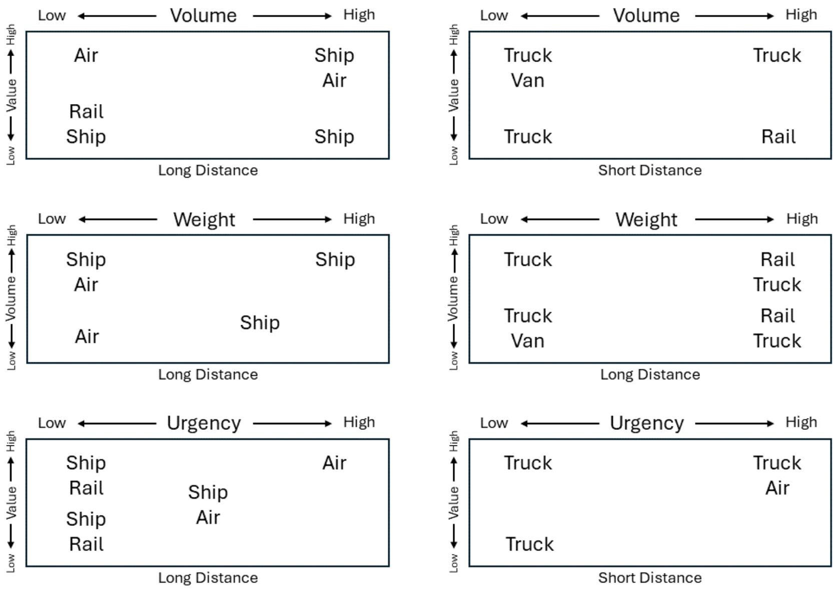

Figure 3-1: Mode Choice Heuristic after Beresford 2021

Such simple selection processes are flawed in two ways: they always result in a single transport mode, and they just consider the costs of the transport itself. For example, the model ignores the perspectives of other actors in the logistic chain who potentially provide the transport vehicles and must take the associated investment costs into account (Cerna

2017). Additionally, it disregards the cost factors that arise pre- or post-haulage or due to specific intermodal solutions, like transshipment costs. This is problematic, because in the context of modal shift reducing the costs associated with switching transport modes is an essential part of establishing competitiveness with alternative transport constellations (Beresford 2021; Santen 2021). In reaction to the increased complexity of cost-oriented mode selection, Engebrethsen 2018 has provided an overview of transportation cost calculations in recent inventory models, investigating the cost effects of combining transport modes.

Statements from stakeholders show that buying trucks is a "much smaller investment and risk" than developing and deploying IWW barges (Roso 2020). Rigorous EU inspections discourage stakeholders from investing in new ships, because they fear the ships will be outdated standard wise before a break-even is attained (Roso 2020), which could mean to operate a vessel some 30 years. Few ship owners investigate alternative fuel systems, because these investments would take "a long time to break even due to the large investments needed" (Roso 2020 after BVB 2017).

Schijndel 2000 provides three cost categories that describe vehicle costs from the owner's perspective

1. Standing costs (irrespective of usage/fixed costs): "include licences, vehicles insurance, driver's wages, rent and rates on premises, interest on capital employed and depreciation of the vehicle"
2. Overhead costs (not attributable to single vehicles): Management, administration, depots, auxiliary fleet
3. Running costs: "fuel, tyres, maintenance and lubricants"

Road transport has usually much lower fixed costs, but higher variable costs (Schijndel 2000)

3.2.2. QUALITY FACTORS

A second category of mode selection criteria can be summarized as quality factors. As Cardebring, Fiedler and Weaver (2000) point out, on the demand side although there is price competition between road and intermodal transport the key difference lies in the quality of services. Also, quality requirements vary markedly between market segments, which have different demands regarding e.g. lead time, reliability and other quality factors.

All quality indicators could be translated into costs via assumptions and further estimations. However, as summarized by Cardebring, Fiedler and Weaver (2000), quality indicators may entail these aspects:

- Lead time
- Reliability
- Flexibility
- Qualification
- Accessibility
- Control
- Security

Some of these factors can be found in overarching structural conditions, such as the maturity of the physical infrastructure a transport mode is operating on or market

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characteristics (Beil 2023; Santen 2021). For example, Cerna 2017 presents the particularities of the national transport infrastructures and its influence on mode selection. More fine-grained quality factors such as transportation control, flexibility, reliability, safety and speed are influenced by these structural conditions. Because these quality factors have an influence on the transit time and the associated time values of goods, they are indirectly cost factors. Harrison 2013 describes the influence of quality factors on transport cost. Varying transport schedules and low transport frequency lead to poor time performance which has a detrimental effect on transport efficiency. Cargo owners may have to compensate for the poor time performance by increasing inventory, thereby binding more capital which in turn leads to higher opportunity costs (Harrison 2013; International Transport Forum 2022). Organizational factors also have a significant influence on transport quality. Santen 2021 investigated the effect of stakeholders' transport mode preferences on the possibility of modal shift from road to inland waterway. They observed a prevalent "business as usual"-mentality, motivating stakeholders to choose those transport modes they are most familiar with (Santen 2021). Other factors are political incentives that motivate shippers to more thoroughly include energy consumption and environmental externalities into their considerations (Beresford 2021). Because by 2016 road transport was responsible for over 97% of all external transport costs, European legislators are interested in implementing alternative, more sustainable transport solutions (Beil 2023).

3.2.3. COST OR QUALITY AS A DECISIVE FACTOR

Comparing the importance of cost and quality factors for shippers' mode choice, the research literature presents a telling picture. Despite the decade-spanning unilateral focus on transport cost, it seems like the ascendence of transport concepts like JIT resulted in a more equalized evaluation of cost and quality factors. Along these lines, Harrison 2013 found that ocean shippers include four quality factors in their five most important decision criteria for mode selection, among them reliability and transport frequency. Yuen and Thai 2015 established similar findings for the customer satisfaction of shippers who assigned the greatest importance to transport speed and reliability. Comparing the relevance of cost and quality factors for improving the chances of a modal shift from road to inland waterway, Santen 2021 conclude that the stakeholder mentality is most important to increase the attractiveness of intermodal transport solutions. Additionally, a feedback loop appears to connect transport quality and transport cost whereby the improvement of quality factors like reliability or frequency is the most promising way for reducing overall transport costs (Harrison 2013).

To determine under which circumstances a modal shift from road to inland waterway can generally be successful, it is necessary to visualize the challenges and potentials that different transport modes exhibit.

When it comes to time-sensible or perishable goods that require a fast, flexible and high-frequence transport, usually road transport is chosen (International Transport Forum 2022). European logisticians benefit from a dense road infrastructure and the comparably low investment costs for new trucks (Cerna 2017).

On the other hand, road transport is confronted with multiple challenges. Frequent road congestions lead to transport delays while the overall transport capacity is restricted by the increasingly scarce driver personnel (Meixell 2008). As shown by Schijndel 2000, trucks

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spend on average between 7.5% and 14.5% of their working time in congestion. Congestions are caused by known bottlenecks in the road infrastructure as well as spontaneous impediments like accidents, vehicle breakdowns or detrimental weather conditions. Furthermore, bulk road transport is generally not possible, because of the regulated truck length, width and height (Beresford 2021). Therefore, the speed of road transport suits the requirements of perishable food products as well as goods that quickly lose their value, e.g. textiles or printed media. Nevertheless, road transport is, as Beresford 2021 puts it, the "natural start-finish mode" and therefore an indispensable part of every intermodal transport chain, independent of good type.

Inland waterway transport benefits from its immense loading capacity, making it a suitable solution for delivering bulk goods such as coal or metal ores (Beresford 2021). It is the transport mode with the highest fuel efficiency, if deployed for bulk goods. As described by Bu 2021, while a truck can move a ton of cargo on average 66 kilometers on a liter of fuel, inland waterway barges reach on average 245 kilometers under the same conditions. Additionally, the infrastructure costs for barge transportation, measured per thousand ton-kilometers, are only a quarter of that for truck transport (Bu 2021). Compared to road transport, recent data from van der Meulen 2023 show that in the Netherland large barges have a competitive advantage regarding costs per ton-kilometer and costs per ton-hour. This advantage applies to dry bulk, break bulk as well as containerized cargo (van der Meulen 2023). Inland waterway transport is also considered a transport mode with comparably small external costs (International Transport Forum 2022). These external costs include air pollution and traffic congestions. Despite these advantages, inland waterway transport is dependent on waterway conditions and the coordination at quays and locks (Santen 2021). Additionally, water transport is seldom a solution for door-to-door deliveries but depends on other carriers to finalize the transport (Beresford 2021).

The rising interest in finding alternatives to road transport solutions sparked research in how modal shifts can take place and which factors are currently preventing them. As the modal shift from road to inland waterway transport will always require some truck transport for the proverbial last mile to the consumer, modal shift is dependent on intermodal transport solutions. An efficient intermodal transport relies on synchronizing different transport modes which is a complex issue (Harrison 2013). Therefore, stakeholders often stick to a business-as-usual mentality, extending existing transport contracts that are regularly adapted to flexible road transport (Santen 2021; Schijndel 2000). In a survey on modal choice for short distance container transport, Meers 2017 has shown that among the logisticians that did not use any intermodal transport services 42% never considered such transport alternatives. This example visualizes the relevant stakeholders' inertia in utilizing different transport solutions. Another factor that is preventing modal shift is the unspecified nature of the parameters that induce change, e.g. which stakeholders to involve in the process, how to distribute responsibilities or how to order and iterate over the relevant activities that help realize a modal shift (Santen 2021).

Kurtulus 2020 who analyzed a comparable modal shift processes from road to rail transport noted that an increase in transport frequency and a decrease in transit time are main benefactors for its success. In case of inland waterway transport, this improvement of quality factors depends on the expansion of waterway transport infrastructure, a point that is also most frequently mentioned by practitioners when it comes to the success of the so-called container on barge transport (Bu 2021). Meers 2017 adds that because of the longer transport time of inland waterway barges compared to road transport, the chances for a modal shift may only be increased by a focus on quality factors like reliability and service frequency. Regarding supportive regulatory measures, Pfoser 2022 describes the possibility of increasing the maximum weight of multimodal truck transports to reduce the number of transshipments and increase the competitiveness of multimodal solutions. Additionally, Santen 2021 emphasizes two target activities that enable a successful modal shift: identifying suitable good flows and including relevant stakeholders. Beil 2023 adds that educating stakeholders on the potential of multimodal transport is vital for changing the mentality of managers and operators as well as reducing existent inertia.

3.2.4. ACTORS' ROLES AND POWERS IN MODAL CHOICE

While cost and quality factors influence the preference for a certain type of transport, the final decision on how these factors determine modal choice lies in the hands of quite many decision makers. In port hinterland transports as subparts of a maritime transport chain, two types of actor coordination can be discerned:

Carrier's Haulage: When a shipping company acts as the organizer of the entire transport chain and markets the pre- and on-carriage to bulk purchasers like forwarders or shippers besides its own ship capacity, then this type of transport is called carrier's haulage.

A special case of carrier's haulage is vertical integration. If a company own ships, terminals, combined traffic (CT) operators as well as railway transport companies, it can organize the whole transport by itself. An example is the A. P. Møller-Mærsk group.

Merchant's Haulage: These transports are organized by actors that are no shipping companies (mostly forwarders or shippers). Usually, they bundle sea freight transport orders. The main challenge of a merchant's haulage is organizing the entire transport chain including the coordination and management of diverse subcontractors.

Decision makers in transport chains – also domestic or continental transports include, shippers, shipping companies, consignees, forwarders, CT operators as well as inland waterway (IWW) operators. To evaluate which actors are entitled to make which decisions, the underlying decision process shall be schematically visualized.

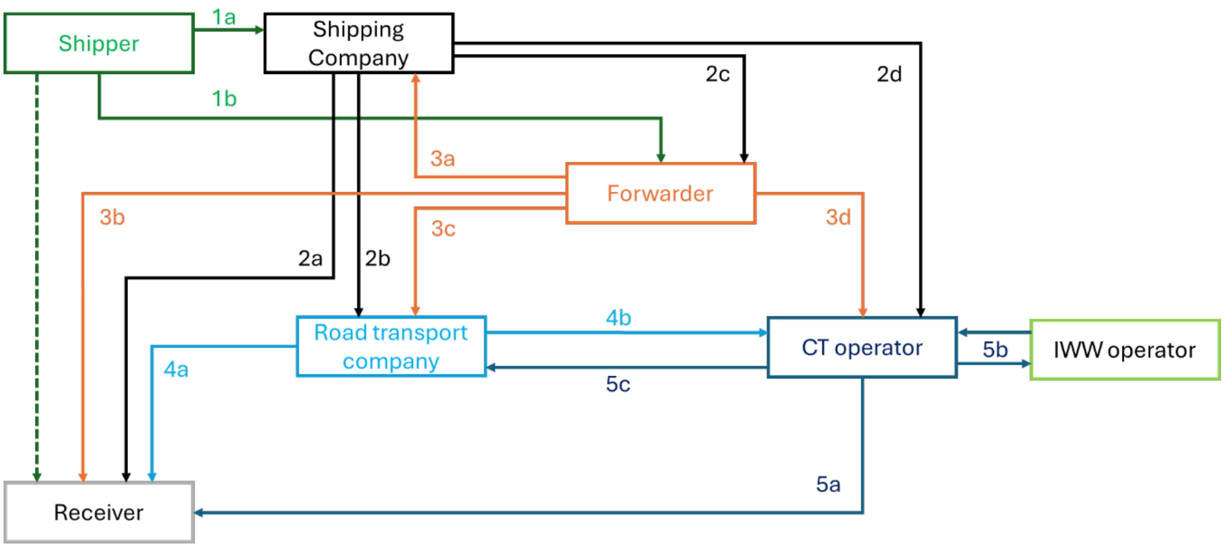

Figure 3-2: Relevant decision makers in intermodal transport

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The decision process of port hinterland traffic starts with the shipper. As he decides about the cargo volume, loading time, destination and time of delivery, the shipper has the greatest decision-making power. He can either directly approach a shipping company (1a) or make use of a forwarder's transport service (1b). The forwarder service can also be part of the shipper's company.

Depending on the organization of the transport chain, the shipping company has different options. If it is part of a vertically organized corporation, it may be able to conduct the transport by itself (2a). The shipping company may instead subcontract another actor for conducting the port hinterland transport. This can either be a road transport company (2b), a forwarder (2c) or a CT operator (2d). The shipping company can freely decide between these options, unless the shipper expects specific requirements to be met.

When the shipper has decided to assign a forwarder (1b), this actor then subcontracts a shipping company (3a). As far as there are no further requirements from the shipper, the forwarder can decide whether to use its own transport fleet for the port hinterland transport (3b) or include a road transport company (3c) or a CT operator (3d).

Road transport companies either conduct the port hinterland transport with their own fleet (4a) or cooperate with CT operators (4b), if it is required by the circumstances or necessary because of profitability considerations.

When a CT operator is involved in the transport chain, he can decide to transport the goods to the receiver by himself (5a) or buy-in transport services from IWW operators (5b) or road transport companies (5c). The CT operator's decision is dependent on his range of services.

IWW operators only act in the transport chain when they are instructed by the CT operator to perform a transport service (5b). It is necessary to clarify that there is no or only very limited interaction between the IWW operator and the receiver of the consignment.

The receiver/consignee is the final actor. At first sight, this actor does not have any influence on the process, because his role is limited to accepting the delivery. But it is imaginable that receiver and shipper are the same actor or that the former can communicate transport requirements to the shipper whereby the receiver would have remarkable influence on the decision process.

3.2.5. CONCLUSION

Mode selection in freight logistics is a nuanced process that goes far beyond simple cost calculations. Modern logistic decisions involve a sophisticated interplay of economic, operational and strategic considerations across multiple stakeholders.

Traditionally, mode selection has been driven primarily by cost, with companies choosing the most economically efficient option. However, modern logistics has evolved to consider a wider range of quality indicators, including lead time, reliability, flexibility and environmental impact. This shift reflects the increasing complexity of global supply chains and growing awareness of sustainability issues.

Road and inland waterway transport each have their own advantages and limitations. Road transport offers unparalleled flexibility, short transit times and extensive network access, making it ideal for time-sensitive or perishable goods. In contrast, inland waterway

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transport excels in the transport of bulk goods, offering superior fuel efficiency, lower operating costs and reduced environmental externalities.

The decision-making process involves several actors, with shippers typically having the most influence. Their choices are influenced by several factors, including cargo characteristics, delivery requirements, infrastructure availability and organisational preferences. Despite the potential benefits of modal shift, many stakeholders display a strong 'business as usual' mentality, preferring familiar transport solutions.

Successful modal shifts require comprehensive strategies that address infrastructure constraints, improve transport quality, reduce transit times and educate stakeholders about alternative transport modes. Intermodal solutions that combine different modes of transport are increasingly seen as a promising approach to overcoming single mode constraints.

Ultimately, transport mode selection is context-dependent, requiring careful analysis of specific logistical needs, economic considerations, and strategic objectives. As global supply chains become more complex and sustainability becomes increasingly important, the ability to intelligently navigate these multifaceted transportation decisions will be crucial for competitive and efficient logistics operations.

3.3 INTERVIEWS WITH STAKEHOLDERS

A questionnaire has been developed to ask stakeholders about their assessment regarding modal choice parameters and past, present and future business assessments. From the interviews an array of fixed inland waterway routes and transport solutions could be identified.

Based on the information provided in the three questionnaires, here is a summary:

3.3.1. IDENTIFICATION AND VOLUMES:

- The respondents represent logistics companies and freight forwarding companies.
- The main cargo types moved are unitized cargo (trailers, containers), shipping logistics (bulk cargo like timber), and project cargo.
- Cargo volumes range from around 400k shipments per year to unspecified volumes.
- The main transport modes used are road (95-98% modal share) and rail, with minimal IWW usage currently.

3.3.2. GENERAL FINDINGS

- Customers mainly choose road transport today due to habit, limited rail connections, and poor reliability of rail.
- Sustainability is rather a secondary factor. There is interest in using IWW transport, especially for longer distances, but availability is very low currently. 30% CO_2 reduction by 2030 and 100% by 2050 is the target. Sustainability is becoming an increasingly important factor, but price is still the primary decision driver.
- The interviewees indicated that no to little market exist for chartering barges on spot and that there only occasionally might be special services that undertake transport offerings outside of the established routes. An interest in establishing a spot market on the inland waterways may also be for a freight forwarder and/or shipper to book individual slots on a container vessel as opposed to booking the entire vessel itself.

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3.3.3. QUALITY FACTORS

- Lead time: Acceptable door-to-door lead times range from 3-4 days for less sensitive cargo to 1-2 days for time-sensitive cargo. Intermodal solutions could have up to 50% longer lead times compared to road.
- Reliability: 90-95% on-time delivery (within agreed time windows) is required. Variance of up to 1 hour early/late is acceptable.
- Accessibility: No set percentage for door-to-door service, but better physical accessibility and more IWW network coverage is desired. Availability and quality of IWW information is extremely important (score of 10/10).
- Control: 100% of shipments require ETA status information. Terminal-in/terminal-out is sufficient, but interim visibility is preferred.
- Safety: 0-1% cargo/load unit damage is acceptable. Zero accidents with personal injury. Safety of IWW should be equal to or better than road.
- Flexibility: Flexibility in last-minute changes and ability to deliver small shipment sizes on-demand is valued. Daily service frequency is seen as the minimum requirement.

3.3.4. COST REQUIREMENTS

- Employee hours: No specific requirements, but efficiency gains through automation could offset any increases.
- Intermodal transport units: All types are used (containers, trailers, swap-bodies), with a pragmatic selection based on the customer requirements.
- Cost: Up to 10% increase over road transport costs is seen as acceptable for intermodal IWW solutions, if offset by other benefits like sustainability, flexibility, and reliability.

Overall, the key themes are the need for reliable, flexible, and sustainable intermodal transport options that can compete with road transport on cost and lead time. Better accessibility and information on IWW services would also drive greater adoption.

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A. ANNEX 1: NUTS REGIONS

Code 2021	Country	NUTS level 1	NUTS level 2	NUTS level 3	NUTS level
BE	**Belgique/België**				0
BE1		Région de Bruxelles-Capitale/Brussels Hoofdstedelijk Gewest			1
BE10			Région de Bruxelles-Capitale/ Brussels Hoofdstedelijk Gewest		2
BE100				Arr. de Bruxelles-Capitale/Arr. Brussel-Hoofdstad	3
BE2		Vlaams Gewest			1
BE21			Prov. Antwerpen		2
BE211				Arr. Antwerpen	3
BE212				Arr. Mechelen	3
BE213				Arr. Turnhout	3
BE22			Prov. Limburg (BE)		2
BE223				Arr. Tongeren	3
BE224				Arr. Hasselt	3
BE225				Arr. Maaseik	3
BE23			Prov. Oost-Vlaanderen		2
BE231				Arr. Aalst	3
BE232				Arr. Dendermonde	3
BE233				Arr. Eeklo	3
BE234				Arr. Gent	3
BE235				Arr. Oudenaarde	3
BE236				Arr. Sint-Niklaas	3
BE24			Prov. Vlaams-Brabant		2
BE241				Arr. Halle-Vilvoorde	3
BE242				Arr. Leuven	3
BE25			Prov. West-Vlaanderen		2
BE251				Arr. Brugge	3
BE252				Arr. Diksmuide	3
BE253				Arr. Ieper	3
BE254				Arr. Kortrijk	3
BE255				Arr. Oostende	3
BE256				Arr. Roeselare	3
BE257				Arr. Tielt	3
BE258				Arr. Veurne	3
BE3		Région wallonne			1
BE31			Prov. Brabant Wallon		2
BE310				Arr. Nivelles	3

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BE32			Prov. Hainaut		2
BE323				Arr. Mons	3
BE328				Arr. Tournai-Mouscron	3
BE329				Arr. La Louvière	3
BE32A				Arr. Ath	3
BE32B				Arr. Charleroi	3
BE32C				Arr. Soignies	3
BE32D				Arr. Thuin	3
BE33			Prov. Liège		2
BE331				Arr. Huy	3
BE332				Arr. Liège	3
BE334				Arr. Waremme	3
BE335				Arr. Verviers — communes francophones	3
BE336				Bezirk Verviers — Deutschsprachige Gemeinschaft	3
BE34			Prov. Luxembourg (BE)		2
BE341				Arr. Arlon	3
BE342				Arr. Bastogne	3
BE343				Arr. Marche-en-Famenne	3
BE344				Arr. Neufchâteau	3
BE345				Arr. Virton	3
BE35			Prov. Namur		2
BE351				Arr. Dinant	3
BE352				Arr. Namur	3
BE353				Arr. Philippeville	3
BEZ		Extra-Regio NUTS 1			1
BEZZ			Extra-Regio NUTS 2		2
BEZZZ				Extra-Regio NUTS 3	3
NL	**Nederland**				0
NL1		Noord-Nederland			1
NL11			Groningen		2
NL111				Oost-Groningen	3
NL112				Delfzijl en omgeving	3
NL113				Overig Groningen	3
NL12			Friesland (NL)		2
NL124				Noord-Friesland	3
NL125				Zuidwest-Friesland	3
NL126				Zuidoost-Friesland	3
NL13			Drenthe		2
NL131				Noord-Drenthe	3
NL132				Zuidoost-Drenthe	3
NL133				Zuidwest-Drenthe	3
NL2		Oost-Nederland			1
NL21			Overijssel		2
NL211				Noord-Overijssel	3
NL212				Zuidwest-Overijssel	3
NL213				Twente	3

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NL22			Gelderland		2
NL221				Veluwe	3
NL224				Zuidwest-Gelderland	3
NL225				Achterhoek	3
NL226				Arnhem/Nijmegen	3
NL23			Flevoland		2
NL230				Flevoland	3
NL3		West-Nederland			1
NL31			Utrecht		2
NL310				Utrecht	3
NL32			Noord-Holland		2
NL321				Kop van Noord-Holland	3
NL323				IJmond	3
NL324				Agglomeratie Haarlem	3
NL325				Zaanstreek	3
NL327				Het Gooi en Vechtstreek	3
NL328				Alkmaar en omgeving	3
NL329				Groot-Amsterdam	3
NL33			Zuid-Holland		2
NL332				Agglomeratie 's-Gravenhage	3
NL333				Delft en Westland	3
NL337				Agglomeratie Leiden en Bollenstreek	3
NL33A				Zuidoost-Zuid-Holland	3
NL33B				Oost-Zuid-Holland	3
NL33C				Groot-Rijnmond	3
NL34			Zeeland		2
NL341				Zeeuwsch-Vlaanderen	3
NL342				Overig Zeeland	3
NL4		Zuid-Nederland			1
NL41			Noord-Brabant		2
NL411				West-Noord-Brabant	3
NL412				Midden-Noord-Brabant	3
NL413				Noordoost-Noord-Brabant	3
NL414				Zuidoost-Noord-Brabant	3
NL42			Limburg (NL)		2
NL421				Noord-Limburg	3
NL422				Midden-Limburg	3
NL423				Zuid-Limburg	3
NLZ		Extra-Regio NUTS 1			1
NLZZ			Extra-Regio NUTS 2		2
NLZZZ				Extra-Regio NUTS 3	3

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B. ANNEX 2: QUESTIONNAIRE

INLAND WATERWAY INTERMODAL TRANSPORT QUALITY AND PRICE REQUIREMENTS SURVEY

This survey aims to understand the quality expectations and price elasticities of users and potential users of intermodal transport solutions. Your feedback will help us design better intermodal inland waterway (IWW) services that meet your needs.

The envisaged intermodal IWW service will be carried out by autonomous vessels.

1 IDENTIFIKATION AND VOLUMES

1.1 IDENTIFICATION

If feasible, please write here the company's name, your name and your contact details.

1.2 VOLUMES

Please indicate the most relevant cargo volumes your company moves on the transport corridors Rotterdam resp. Ghent to/ from the European hinterland.

Please fill in the table hereunder:

Commodities (name or NST classification) Volume in the year 2022 Unit of volumes in tonnes, TEU or shipments transport mode(s) chosen (in % of modal share) Main Origin-Destination

1.3 GENERAL QUESTIONS:

Why do your customers choose a certain transport mode today, and, if you have the freedom to make that choice, what do you base this choice on?

2 QUALITY REQUIREMENTS:

2.1 LEAD TIME:

What is the acceptable door-to-door lead time for your shipments? (Please specify in hours:minutes and indicate roughly the Origin Destination regions.)

Compared to single-mode road transport (indexed at 100, road transport lead time today equals 100), what is the maximum acceptable lead time index for intermodal transport (e.g. 100 (same) or 120, would mean 20% longer)?

2.2 RELIABILITY:

What percentage of shipments must be received within the planned delivery time (± 60 minutes) for you to consider the service reliable?

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What is the acceptable variance in delivery time (hours: minutes)? Is there any difference for early or late delivery?

What is your quality assumption regarding autonomous intermodal IWW solutions regarding the reliability compared to road only transport? (Road indexed as 100)?

2.3 ACCESSIBILITY:

What percentage of your shipments should be able to be booked and carried out door-to-door without other intermediate service providers?

On a scale of 0 (not accessible) to 10 (fully accessible), how would you rate the required physical accessibility of IWW intermodal transport services from your typical origin of the cargo? If a truck pre-haul and/or end-haul is mandatory, please indicate.

On a scale of 1 (not important) to 10 (extremely important), how would you evaluate the required availability and quality of IWW intermodal transport information (e.g. schedules, any special load unit requirements, required cargo pre-announcement, with your operation in mind)?

Please add details

2.4 CONTROL:

For what percentage of shipments is it acceptable NOT to receive status information about the Estimated Time of Arrival (ETA) when requested?

Is the message terminal-in / terminal-out as a status information for your shipment regarded as sufficient?

2.5 SAFETY

What is the maximum acceptable share of load units or cargo being damaged per year (in percentage)?

What is the maximum acceptable number of accidents with people being harmed per year?

What is your experience or your assumption (please state which it is) regarding the safety of IWW intermodal transport compared to road transport, road transport being indexed at 100? Please state the index for IWW intermodal transport.

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2.6 FLEXIBILITY:

How many hours' notice would you require in advance of changing "last minute" a transport demand order (cancellation or booking extra capacities)?

One idea of small autonomous barges is to shorten the reaction time to transport demands. Do you require some flexibility in delivering "any" amount of cargo to "any" location, at "any" time? Any amount is meant as also small shipment sizes? Please elaborate:

2.7 FREQUENCY:

What is the minimum required number of departures per week for the door-to-door intermodal transport chain?

2.8 ENVIRONMENTAL REQUIREMENTS:

Is emission-free transport a requirement for your shipments? If yes, what is the approximate desired reduction in CO_2e emissions compared to road transport (in %)?

Have you observed a trend among your customers in recent years that sustainability is becoming more prioritized as a quality indicator.

3 COST REQUIREMENTS:

3.1 EMPLOYEES

Compared to the current total manhours of employees involved in your supply chain per shipment per year (indexed at 100), what is the maximum acceptable indexed value for an intermodal transport solution?

3.2 INTERMODAL TRANSPORT UNITS USED

Which ITUs do you use? Indicate if maritime (ISO) containers (pallet-wide containers) any other container type (open top), swap-bodies or semi-trailers. Indicate the share of the types.

3.3 INTERMODAL TRANSPORT UNIT REQUIREMENTS:

Compared to recent costs for equipment (swap-bodies, containers, semi-trailers) and infrastructure (e.g. ramps) for road transport (indexed at 100), what is the maximum acceptable indexed system cost for changing necessary load units for the intermodal transport chain? Would you at all change to stackable units if you don't use them right now? Or wouldn't there be any change needed? Please elaborate.

3.4 PRICE PER SHIPMENT

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Compared to the estimated cost for a door-to-door shipment via single-mode road transport (indexed at 100), what is the maximum acceptable indexed cost for an intermodal transport solution?

Please provide any additional comments or requirements:

Thank you for your valuable input! Your responses will help us develop better intermodal IWW transport solutions tailored to your needs.

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