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Freight mode choices for eco-friendly transport modes: An impact-analysis of modal shift measures

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Abstract

For years, numerous studies have demanded a greater shift of freight transport from road to eco-friendly transport modes to prevent serious consequences of climate change. Despite these scientific claims, road transport is still the predominant transport mode in the sector. A key element to increase modal shift is to transform freight mode choices, as they have a decisive impact on the selection of a transport mode based on identified transport performance criteria. Nevertheless, there exists a lack of academic research examining the relationship between modal shift measures and mode choice criteria, as most studies focus on only one area without analysing the influences. By means of a survey-based assessment encompassing 131 responses from shippers and logistics service providers in Austria, Germany, and the BeNeLux states, a user-centric framework was established to identify the most influential modal shift measures on freight mode choice criteria. The results show that *developing infrastructure* and *improvements of services and efficiency* are the most important measures impacting mode choice criteria and consequently might bear the potential to lead to a transformation towards modal shift. Additionally, the paper underlines that an adaption of freight rates is necessary since the transport price is still the most important mode choice criteria.

Keywords: modal shift; freight mode choices; policy measures; transport mode; eco-friendly transport

1. Introduction

The transport sector is a major contributor to global pollution and accounts for 23% of global greenhouse gas emissions (Greene and Lewis 2019), increasing the challenges of climate change and accelerating the achievement of the global 1.5 degree and 2-degree limits. This has implications that are likely to be catastrophic for the quality of the

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global environment (McKinnon et al. 2015). Looking more closely at emissions from the freight sector, road transport emerges as a significant contributor (Eurostat 2021). To mitigate the climate risks caused by the transport sector, the European Union has called for a 90% reduction in emissions from the sector by 2050, based on the publication of several targets in the European Green Deal. A key objective of the European Green Deal for the transport sector is the requirement to reduce the current imbalance between transport modes and to shift a significant proportion of the 75% of inland freight transported by road to rail and inland waterways (European Commission 2019). A year after the publication of the EU-Green Deal in 2020, the European Commission (EC) published the Sustainable and Smart Mobility Strategy, in which more precise goals for the transport sector were published. This strategy paper set the clear target of increasing rail freight transport by 50% by 2030 and doubling it by 2050, as well as increasing inland waterway transport by 25% by 2030 and 50% by 2050 (European Commission 2020). Nevertheless, the current modal split in European countries is far behind the goals of the EC and road transport has even increased heavily in the past (McKinnon et al. 2015; Pinchasik et al. 2020). The most recently published figures for modal split show that road freight transport accounts for 77.4 % of the total inland freight transport, followed by rail (16.8 %) and inland waterways transport (5.8 %) in the European Union (Eurostat 2021).

Given the ambitious modal shift targets and the need for significant transformations in the transport sector (ITF 2022), further research is needed to analyse different approaches to achieve these objectives. Several papers have already highlighted the necessity to focus more on freight mode choices (e.g. Kaack et al. 2018; Zeybek 2019; Bask and Rajahonka 2017; Pinchasik et al. 2020). Freight mode choices describe the selection of a transport mode based on identified transport performance variables such as cost or speed and the fulfilment of these variables (Monczka et al. 2016), and could allow a stronger modal shift (Stockhammer 2021). Due to the increasing importance of eco-friendly transport, the environmental aspects of the individual modes of transport are given greater importance. The various transport modes generate different levels of external costs, which are costs related to congestion, air pollution, climate change, accidents and noise, which are generally not borne by the transport sector. It becomes even more necessary to understand the externalities of each transport mode (Schroten et al. 2019). Accordingly, freight mode choices are crucial for the emissions caused by a transport option, as each decision for a particular transport mode has a different impact on the environment (Bask and Rajahonka 2017).

However, the analysis of several studies revealed that there are few academic results examining modal shift measures in terms of the decision criteria for freight mode choices in Europe. While many studies were found that analyse either modal shift or mode choice, there is a lack of academic research that examines the relationship between these two areas. Therefore, we investigate which modal shift measures have a significant impact on the choice of a transport mode using a user-centric framework. A user-centred approach was adopted to gain a comprehensive understanding of the decision-making processes involved in freight mode choice. This approach prioritised the perspectives and preferences of decision makers involved in freight mode choice. The use of a survey-based analysis provided valuable insights that allowed a more sophisticated understanding of the factors influencing decision making from the perspective of the practitioners themselves. The survey was aimed at professionals involved in freight mode choices, including both shippers and logistics service providers (LSP) in Austria, Germany and the BeNeLux states. The overall objective is to identify the most influential modal shift measures on freight mode choice criteria guided by the following research question: Which modal shift measures are capable of significantly influencing the criteria for the choice of a transport mode? The theoretical basis for the quantitative analysis is a systematic literature review by Beil and Putz-Egger (2023), in which eleven crucial modal shift measures, divided into six modal shift segments, were identified. These identified measures guide this paper. The results will serve to shape further research directions and support policy makers and institutions in developing and implementing well-founded modal shift strategies to achieve the defined climate targets.

The remainder of this paper is structured as follows: Section 2 describes the theoretical background and existing work on freight mode choices. Section 3 describes the research framework and hypotheses followed by section 4 describing the research methodology used for this study. The results of the quantitative survey are shown in Section 5. Section 6 presents the conclusions of this paper and recommendations.

2. Freight mode choices

The examination of freight mode choices is essential for the development of modal shift measures, considering that they are a highly complex part of transport planning involving a wide range of factors. Freight mode choices can be defined as the selection process to choose the most appropriate mode for a company's freight activities (Meixell and Norbis 2008). In scientific literature, the mode choice process is a highly discussed topic and has been of continued interest over the last decades (Zeybek 2019; Moschovou and Giannopoulos 2010).

2.1. Decision makers

Researchers paid great attention towards identifying the actual decision-makers involved in freight mode choices. In most mode choice models, it is assumed that the decision maker is the shipping company, due to its demand for transport services. Shippers then have a choice to complete the shipping itself or outsource it to a logistics service provider (Jong 2014). The logistics service provider has the practical role of organising the transport, while the decision is strongly influenced by the shippers' preferences in terms of environmental, financial and technical requirements (Nocera et al. 2018). Furthermore, freight mode choices by shippers are often made within a greater logistics or even supply chain context, involving several decision-makers on different levels of hierarchy (Eng‐Larsson and Kohn 2012). A lot of studies exist which assume that the shipper is mainly responsible for the selection of the right transport mode (e.g. Arencibia et al. 2015; Brooks et al. 2012; Kaack et al. 2018). For example Jong et al. (2001), confirm through a disaggregated logit model, that shippers are the actual decision maker, while LSP are only responsible for the route selection. In contrast, Bergantino and Bolis (2003) claimed, through a combination of revealed preferences and adaptive stated preference experiments towards the intermodal maritime freight transport, that within more than half of mode choice processes, the LSP is the decision maker. They note that due to the increasing number of outsourced activities, it is becoming more common for the shipper to delegate the mode choice to third parties, especially for medium and long distance shipments (Bergantino and Bolis 2003). Therefore, Konstantinus and Zuidgeest (2019) conducted a literature review and analysed 17 studies to determine whether either the shipper or the LSP is considered the actual decision maker. Out of these 17 studies eleven indicated the shipper, three indicated the LSP, and another three indicated that both were the decision makers. To sum up, Jong (2014) suggests instead of assuming that only one of the involved stakeholders takes the decision on its own, it should be seen as a joint decision based on the interaction.

2.2. Decision criteria

Another widely discussed area by researchers is the definition and evaluation of criteria for freight mode choices. Within the mode choice process numerous different criteria are considered and therefore it is vital to understand which criteria influence the mode choice process the most (Bask and Rajahonka 2017). The output of the following literature analysis of decision criteria serves as a basis for the hypothesis creation later in the paper.

A majority of studies conclude that the transport price is the most crucial criteria in freight mode choices (e.g. Cullinane and Toy 2000; Grue and Ludvigsen 2006; Kreutzberger 2003). Rating the most influential criteria for freight mode choices has always been a major concern amongst transport scientists. McGinnis (1990) assessed twelve studies regarding the mode choice process in the United States before and after the 1980 transport deregulation process. The author identified the six key attributes transport price, reliability, transit time, safety, shipper market considerations and carrier considerations, but without ranking them. The study was concluded by the statement, that the importance of freight rates was consistently high, closely followed by service criteria. However, any generalisation of importance should be qualified because some service criteria may be more important than freight rates (McGinnis 1990). This study was then revised by Murphy and Hall (1995) who ranked the key attributes as follows:

1. Reliability (reliability, delivery time)
2. Freight rate (costs, charges, rates)
3. Carrier considerations (availability, capability, special equipment, financial stability)

4. Transit time (time-in-transit, speed, delivery time)
5. Shipper market considerations (customer service, user satisfaction, market competitiveness)
6. Safety (loss, damage, claims processing, tracing)

Five years later, Cullinane and Toy (2000) identified, through a stated preference experiment based on a content analysis of 75 studies, 15 different criteria used in freight mode choices. Through a meta-analysis based on appearances of quantifiable factors the criteria were ranked and the five most important were (1) transit time reliability, (2) transit time, (3) freight rates, (4) safety and (5) service availability.

Another extensive survey involving 246 interviews with LSP and shippers regarding the identification of the most influential determinants of freight mode choice in the intra-European freight transport market, Grue and Ludvigsen (2006) showed that reliability and transport costs are the most important freight mode choice criteria. In the survey the respondents were asked to rank 23 different freight mode choice criteria by their importance.

Beuthe and Bouffioux (2008) analysed the relative importance and value of qualitative freight mode choices criteria through a stated preference experiment with only shippers. Through a conditional logit model, the qualitative factors service frequency, transport time, reliability, flexibility, and safety were analysed. The experiment showed that these qualitative factors play a major role in freight mode choices. Likewise, the authors again claimed that the relative importance of the chosen criteria strongly varies according to subsamples. These differences are a result of diverging transport management processes within companies based on type and value of goods, distance and time of transport demand, internal and external logistics and the configuration of the network.

With these findings the question arises if the influence of the identified freight mode choice criteria is changing from the past to the present. Lammgård and Andersson (2014) analysed this issue with two similar studies nine years apart. A survey was conducted in 2003 with 406 respondents and a survey in 2012 with 175 respondents regarding the purchasing of freight transportation services among large shippers in Sweden. The study showed that the most important factors such as costs, reliability as well as transport quality remain stable over time. The top five freight mode choice criteria in the 2012 survey held a top ranking in 2003.

The studies identified have shown that both the price and the reliability are consistently cited as being among the most important criteria when choosing a mode of transport. Another literature review by Reis (2014), focusing on mode choice variables in short-distance intermodal freight transport, came to the conclusion that only a limited set of criteria are consistently relevant, while most others are influential only in specific settings. The author used an agent-based model to simulate the behavioural reactions of transport agents and reveals that this limited set of freight mode choice criteria includes transport price, reliability, flexibility, and transit time.

One of the latest studies on freight mode choice decision criteria by Zeybek (2019) conducting interviews with LSPs and shippers in Europe came to a similar conclusion. In all cases the most crucial factor related to freight mode choice is cost, nevertheless the shippers and LSP need confidence that transit time and safety will be achieved. In summary, although there are a variety of criteria for freight mode choices, the following four are consistently relevant: transport price, reliability, flexibility and transit time. These four criteria serve as a basis for the hypothesis development in the further course of this paper.

3. Research framework and hypotheses

The research framework of this paper consists of the identified modal shift measures segments by Beil and Putz-Egger (2023) and the four mode choice criteria, transport price, reliability, flexibility and transit time (section 2.2.). To test the impact of the modal shift measures on the mode choice criteria for freight transport, statistical hypotheses were formulated. A total of eight hypotheses (*H1-H8*) were formed to define the influence of shippers and LSP in freight mode choices, decision criteria and the analysis of the impact of the six modal shift measure segments on these criteria.

3.1. Modal shift segments

This study builds upon a classification framework proposed by Beil and Putz-Egger 2023 for categorizing modal shift measures into six segments. These segments enable the classification of measures that facilitate the transition to eco-friendly transportation modes. To provide a comprehensive understanding of the measurement segments and the associated measures, Table 1 presents an overview of the measurement segments alongside all the measures employed, as per the classification by Beil and Putz-Egger 2023.

Table 1: Overview of modal shift segments and measures

Segment	Measures
Taxation measures	Internalization of external costs
Regulation measures	Increased weight limits for mulimodal pre- and post haulauge
	Speed, weight and route regulations on the road
Infrastructural measures	Increased capacities among rail and inland waterways
	Expansion of existing infrastructure
	Renovation of existing infrastructure
Informative Measures	Awareness raising activities of relevant stakeholders
Standardization and harmonization measures	Harmonization of legal framework
	Service and efficiency improvements
	Decreasing multimodal transit-times
Financial incentives	Incentives through subsidies

3.2. Decision maker of freight mode choices

To target modal shift measures for actual decision makers it is important to understand which stakeholders are involved and to what extent. In the literature, it is often assumed that the decision maker is a single institution (LSP or shipper), which means that either only the shipper or only the LSP takes the decision, without taking into account that both have a certain influence (Jong 2014; Konstantinus and Zuidgeest 2019). Most studies imply that the shipper is the decision maker, however, there are other studies that contradict these statements and imply that the LSP or even the forwarder or carrier are heavily involved in the process (Bergantino and Bolis 2003). Therefore, it is necessary to determine the extent of their influence. To find out which interest group is the actual decision-maker in the choice of transport mode and how they perceive the influence of the other group, the following hypothesis is put forward:

H1: Shippers and LSP agree that both have an equal influence on the modal decision.

3.3. Freight mode choice criteria

The overall output of section 2 was that the four factors transport price, reliability, flexibility and transit time are the most important. In the context of this literature analysis, a vast number of studies conclude that either price or reliability are the most relevant criteria when choosing a certain transport mode. For example, the ranking of Murphy and Hall (1995) and Cullinane and Toy (2000) showed, that the importance of reliability is ranked higher than freight rates. On the other hand Reis (2014), argues that only price would encourage freight LSPs to favour multimodal services. Thus, the following hypothesis analyses the criteria preferences of shippers and forwarders regarding the most important criteria when choosing a transport mode:

H2: Respondents rank the criterion transport price more important than the criterion reliability when choosing the mode of transport.

3.4. Impact analysis of modal shift measures

Taxation measures: The category of taxation measures modifies market prices of transport services in order to enhance a modal shift to other transport modes (Liedtke and Carrillo Murillo 2012). In this regard the internalization of external costs was mostly discussed, in order to create taxes based on the "polluter pays" principle, introduced by the *European Green Deal* (European Commission 2019). Since the *European Green Deal* and the *Fit for 55* strategy by the EC call for a stronger balance of freight rates through CO2 taxes (European Commission 2021), the following hypothesis is formed, to test whether the respondents agree to an effect:

H3: The majority of respondents believe that taxation measures towards modal shift influence the mode choice criteria transport price.

Regulatory measures: The regulatory measure category refers to either an increase in road transport regulations or a decrease regulations and barriers for multimodal services. While lowering restrictions would promote higher flexibility for multimodal services (Pfoser 2021), increasing road regulations would reduce flexibility of transport services, due to higher burdens of the transport planning process (Behrends 2017). Consequently, the category of regulation measures influences the mode choice criteria flexibility:

H4: The majority of respondents believe that regulation measures towards modal shift influence the mode choice criteria flexibility.

Infrastructural measures: Blauwens et al. (2006) and Islam et al. (2016) state that infrastructural measures as an expansion and renovation lead to an increase in capacity, which leads to the possibility to operate heavier, long and faster means of transport. Both authors conclude that this increases the overall attractiveness of eco-friendly transport modes and lead to a reduction in operating costs. Therefore, the following hypothesis is proposed:

H5: The majority of respondents believe that infrastructural measures towards modal shift influence the mode choice criteria transport price.

Informative measures: Informative measures should enhance a stronger "mental shift" among shippers and LSPs, aiming to increase the awareness of the need to use more eco-friendly transport modes (Meers and Macharis 2015). Currently there is a lack of information among shippers and LSP regarding the possibilities of the usage of rail and inland waterways. This shortage of information leads to an inequitable use of transport modes, so that road transport is often preferred because decision makers are unaware of alternatives. They stick to tried and tested options and tend to make decisions based on currently accessible information (Stockhammer et al. 2021). Therefore, it is important to understand that this behaviour is affecting the quality of decisions which is leading to a distortion in the demand for eco-friendly freight transport (Gibbons et al. 2014). Informative measures play a crucial role in significantly increasing the reliability of freight mode choices. They provide decision-makers with comprehensive knowledge about alternative transport modes beyond road transport, enabling them to make informed and dependable decisions. By deepening decision-makers' understanding of the application of different transport modes and showcasing the wide range of reliable options available in the market, these measures effectively enhance decision-makers' confidence in considering and selecting eco-friendly transport modes (Cichosz and Pluta-Zaremba 2019). Therefore, the following hypothesis is formed:

H6: The majority of respondents believe that informative measures towards modal shift influence the mode choice criteria reliability.

Standardization and harmonization measures: The measures of the standardization and harmonization category refer to an increase of international harmonization, efficiency improvements and a decrease in multimodal transit times. Most of the identified studies dealing with this measure category discuss activities such as an increase of service reliability, due to an overall increase of the transport service quality (Blauwens et al. 2006; Islam et al. 2016; Pfoser

2022). Consequently, these measures would have an influence on several freight mode choice criteria. Based on these papers, the following hypothesis is proposed:

H7: The majority of respondents believe that standardization and harmonization measures towards modal shift influence the mode choice criteria reliability.

Financial incentive measures: The financial incentives measure category is mainly dealing with the implementation of subsidies or discounts on eco-friendly transport modes. The aim is to increase the attractiveness of eco-friendly modes of transport through incentives set mainly by governments, leading to better freight rates (Gonzalez-Aregall et al. 2021). Therefore, the following hypothesis is formed:

H8: The majority of respondents believe that financial incentive measures towards modal shift influence the mode choice criteria transport price.

4. Methodology

The analysis of multiple studies revealed that there are few scientific results analysing modal shift measures in terms of decision criteria for freight mode choices in Europe. Many studies were found analysing either modal shift or mode choice, but there is a lack of academic research examining the relationship between these two areas. Given the existing research gap, it was considered essential to collect primary data through a user-centric framework including stakeholders involved in freight mode choices. The application of a user-centric approach, coupled with quantitative survey analysis, allows for an in-depth analysis of the impact of modal shift measures on freight mode choice criteria. This approach has significant value as it focuses on understanding the perspectives and preferences of decision makers who are actively involved in freight mode choice. This user-centric perspective enhances the practical applicability and effectiveness of modal shift policies, thereby facilitating more informed freight decision making. Based on the previously identified literature on freight mode choices supplemented by a systematic literature review on modal shift measures by Beil and Putz-Egger (2023), a standardised questionnaire was designed according to Mayer (2013).

4.1. Development of the questionnaire

The development process of the questionnaire was conducted in three steps. First, as a general structure, the required focus areas for the impact analysis were defined in the questionnaire. Second, the draft questionnaire was tested in a pre-study as suggested by Flynn et al. (1990). For the pre-test experts (5 LSPs and 3 shippers) were asked to complete the questionnaire. Third, a general revision and modification of the questionnaire was made based on the feedback received. The pre-study was conducted to increase the reliability of the questionnaire and to obtain feedback on the structure and clarity of the questions. The final questionnaire consists of four segments: demographics (D), mode choice (M), and modal shift segments (MS). The first segment analyses demographic data such as gender, country, company size and type. The second segment, mode choice, analyses the transport modes used, the length of transports, and the criteria for mode choice. The final segment examines the impact of each category of modal shift measures on freight mode choice criteria. Figure 1 visualizes the questionnaire segments with the different categories.

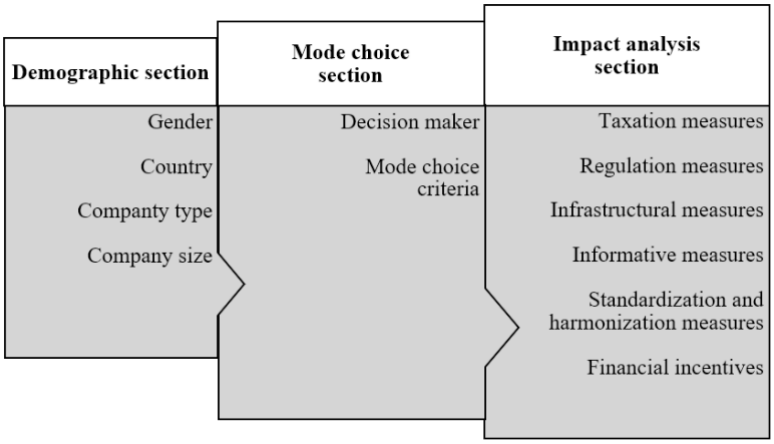

Fig. 1 Structure and content of questionnaire segments

Each question was mandatory, ensuring that no missing values could be generated, apart from the *not sure* response options, which represented a small number of responses. Only closed questions were used, which were divided into dichotomous or multi-categorical questions. In the section on demographic data and mode choice, mainly multi-category questions were used according to Schnell (2019). To answer the questions regarding the decision maker and the mode choice criteria a Likert Scale was used. In the impact analysis section, dichotomous questions were used in which respondents indicated for each measure segment whether they expected an impact on a specific mode choice criterion or not. According to Cohen et al. (2018) the option *not sure* was provided to enable an exit for respondents who want to avoid answering, either because they do not have enough knowledge to answer the question or because they do not want to answer the question because of its sensitive nature.

4.2. Data collection and sampling strategy

The data collection took place from March 04, 2022, to April 15, 2022. The questionnaire was built as a web-based survey using a web platform. The survey was sent out per e-mail and newsletters with a target audience of shippers and LSPs, with an explanatory cover letter and the link to the web-based survey. The survey was directed at companies that operate in the freight transport industry, either listed as logistics companies or cargo owners, i.e., companies which are shippers or logistics service providers. To ensure that the right person receives the survey, the e-mail indicated that the survey is addressed to employees involved in the mode choice process in their company. To achieve high validity of the sample, it is important that homogeneous groups are selected (Ghauri et al. 2020). For this survey, non-probability sampling according to Cohen et al. (2018) was applied, since the narrowly defined target group does not allow probability sampling. Non-probability sampling is a purposive sample mainly used when the target group is partly complex or difficult to target. However, a disadvantage of this method is that some members of the wider population may be excluded. The geographical area was mainly narrowed down to Austria, Germany and the Benelux states, due to the existing network of contacts. We contacted in total 229 people directly and published the survey in various newsletters related to the logistics industry to achieve a high reliability of the results. As a result, a valid sample of 131 responses was obtained. Unreliable responses ($n = 5$) were eliminated from the sample to ensure consistency and accuracy.

4.3. Data analysis

The paper consists of 8 hypotheses, with hypothesis *H1* analysed by a non-parametric test (Mann-Whitney U-test) based on ordinally scaled data and hypothesis *H2-H8* tested by a comprehensive descriptive analysis. For data analysis, we used SPSS v27 software. To analyse the nature of the variables, a Kolmogorov-Smirnov test was used, which resulted mainly in skewed results of the data.

5. Results

In this section, the results of the data analysis are presented and discussed based on the rejection or retention of the hypotheses. To provide an overview of the demographic data of the respondents, Table 2 was provided. It must be noted that the study is only representative for the selected geographical area of the respondents.

Table 2. Demographic data of the sample *(N = 131)*

Category	Characteristics	*N*	%
Gender	Female	30	23%
	Male	101	77%
Country	Austria	93	71%
	Germany	21	16%
	BeNeLux	17	13%
Company Size	< 249 employees	57	44%
	> 250 employees	74	56%
Company type	LSP	69	53%
	Shipper	62	47%

5.1. Decision maker of freight mode choices

This section examines the influence of the involved stakeholders regarding freight mode choices and analyses hypothesis *H1*, which states that freight mode choices are equally influenced by the shipper and the LSP. Respondents could indicate the extent of the influence of shippers and LSP on a 5-point Likert scale from "no influence" [0] to "high influence" [4]. While most scientific papers aimed to identify the single actor making the decision, this study considered neither of them (shipper or LSP) as the sole determinant and aimed to find out who is more influential. Since the variable "influence of shippers on freight mode choices" is not normally distributed, we will use non-parametric procedures to analyse our hypothesis.

Considering the nature of the two variables under investigation, the dependent variable (shippers influence) is ordinally scaled and the independent groups (shippers and LSP) are unpaired, which is why we choose the Mann-Whitney U-test, as suggested by Neely et al. (2003). Table 3 presents a summary of the results from the Mann-Whitney U test.

Table 3. Results of analysis of influence of shippers and LSP on freight mode choices

Influence of shippers in freight mode choices	*N*	Mean	Median	SD	Mean Rank
Shipper	62	2.47	3.00	1.302	70.40
LSP	69	2.25	2.00	0.898	62.04
			Mann-Whitney *U*		1866
			Z		- 1,307
			p-value		0.191

The table shows the results of the Mann-Whitney U-test with a significance level of 0.05 indicating that the opinions of shippers (*mean rank = 70.40*) are not significantly divergent from those of LSP (*mean rank = 62.04*) in terms of their influence on freight mode choices (*p = 0.191*). Therefore, hypothesis H1, which states that shippers and LSP

agree that they have a similar impact, can be retained. The mean values of shippers ($\mu = 2.47; \sigma = 1.302$) and LSP ($\mu = 2.25; \sigma = 0.898$) are in the middle range of the 5-point Likert scale, without a strong tendency in any direction, indicating that both agree to have a powerful influence.

5.2. Freight mode choice criteria

The following section focuses on examining the importance of the four criteria for freight mode choices: transport price, reliability, flexibility, and transit time. As part of this analysis, hypothesis *H2* is tested to determine whether either reliability or transport price is more important when choosing a mode of transport. To avoid bias concerning this question, the four main criteria were given instead of simply listing the transport price or reliability, as other criteria may also be in the top two positions. By using a 7-point Likert scale the respondents rated the importance of these four criteria. Table 4 shows the descriptive data of each criterion.

Table 4. Descriptive data on each mode choice criteria

Importance of freight mode choice criteria	Mean	Median	SD	Coefficient of variation
Transport price	5.88	6	1.103	18.75
Reliability	5.76	6	1.222	21.21
Transit time	5.50	5	1.418	25.75
Flexibility	4.89	6	1.326	27.13

With respect to the mean values, the highest score is for the criteria transport price, closely followed by reliability. The lowest score is related to flexibility, which has quite a high standard deviation, which indicates a rather low agreement on these criteria. To test hypothesis *H2* a figure 2 is provided, showing the distributions of the two focused criteria.

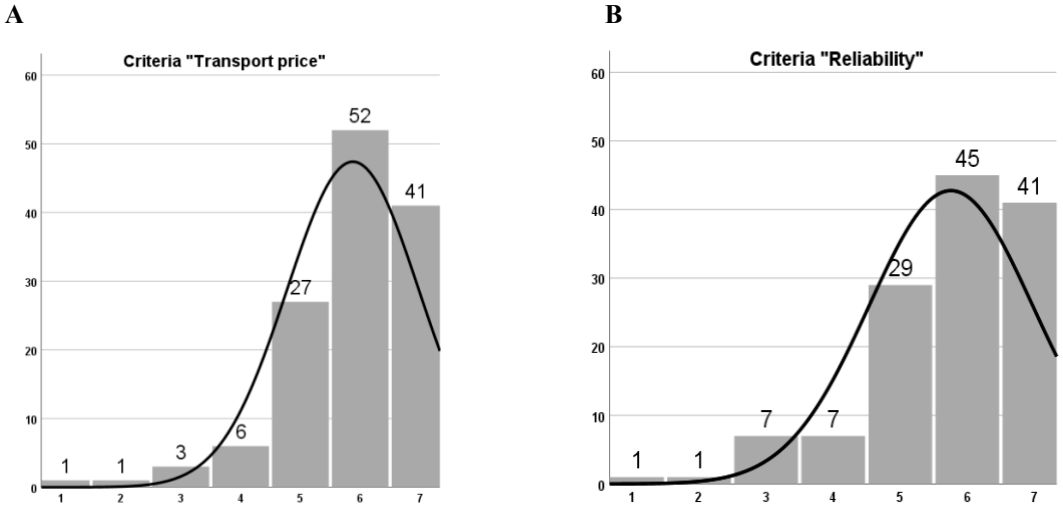

Fig. 2. Histogram of freight mode choice criteria transport price (A) and reliability (B)

The two histograms show a relative similar distribution of the Likert scale. The mean of reliability is 5.76 ($\sigma = 1.222$) while the mean of transport price is 5.88 ($\sigma = 1.10$). The highest value [7] was chosen by the same number of respondents, while the other values vary slightly although remain similar. Looking at these values, hypothesis H2 is accepted, as the transport price is rated higher, but with a very small gap to the criterion reliability. This result is in line with the findings of Reis (2014) and highlights that the transport price is indeed the criterion that takes the central

stage when it comes to changing freight mode choices through modal shift measures. Measures promoting a change in prices either through an increase in of road transport or a decrease in favor of eco-friendly modes. However, as all four criteria are assessed rather similarly, the impact of modal shift measures on each criterion should not be considered in isolation.

5.3. Impact analysis of modal shift measures

The following section presents the results of the analysis of modal shift measures and their influence on the four freight mode choice criteria: transport price, reliability, transit times and flexibility. For each measure segment, respondents were given the opportunity to indicate whether they expect an impact on the criteria mentioned (dichotomous variables). They were also provided with the option to indicate that they are not sure of an impact. This allows us to analyse which measure segments could cause a change in freight mode choices. Considering the reason for using dichotomous questions and not assessing the magnitude, it is important to mention that this is a hypothetical question type and the "expected" impacts are not yet known to the respondents. Therefore, only a yes/no answer type was used to increase the representativity of the result.

Hypothesis *H3* deals with the impact analysis of taxation measures, mainly related to the ‘internalization of external costs’, on the transport mode choice criteria transport price. Observing the proprtions, the criteria transport price received the highest value (*existing influence = 89 %*) being the single criteria with a mode of one, which shows the majority of respondents agree that there is an influence on transport price. In addition, the selection option *not sure* received a rather low mean score, indicating that respondents are confident that taxation measures have a certain influence on freight mode choices. The criteria with the second highest mean score is transit time with a relatively low value (*existing influence = 17 %*). To receive a broader overview of the frequencies, the percentages of each freight mode choice criteria are shown in the following figure.

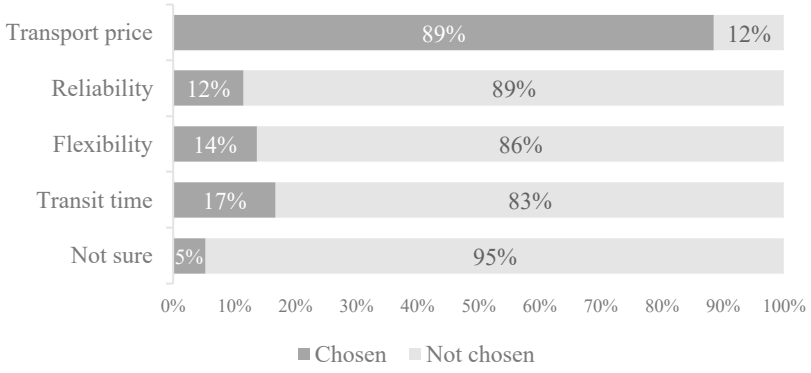

Fig. 3. Shares of mode choice criteria on taxation measures

The visualization of the frequencies reveals that most of the respondents expect taxation measures to have an impact on the mode choice criteria transport price. Therefore, hypothesis H3 is confirmed.

Hypothesis *H4* addresses the analysis of the impact of regulatory measures, which are mainly dedicated to weaken the road freight transport and attracting multimodality, on the mode choice criteria flexibility. The criteria flexibility has the highest influence (*existing influence = 64 %*) according to the respondents, closely followed by the criteria transport price (*existing influence = 58 %*). Both measures display a mode of one, which signifies that the majority of respondents agree that there is an influence on these two criteria. Only four respondents used the *not sure* selection option. The frequencies to each criteria are shown in Figure 4.

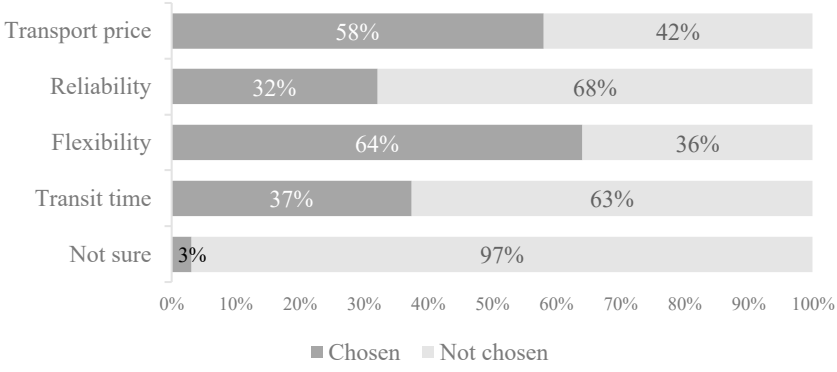

Fig. 4. Shares of mode choice criteria on regulation measures

The impact analysis of the regulation measure segment indicates that its influence is mainly on the criteria of flexibility, therefore, hypothesis *H4* is confirmed. Nevertheless, it is relevant to mention that many respondents identify a also high impact on the criterion transport price.

Hypothesis *H5* addresses the analysis of the impact of infrastructural measures, which are mainly dedicated to the renovation and expansion of existing multimodal infrastructure, on the mode choice criteria transport price. The distributions indicate that the infrastructure measures segment received a high impact on all mode choice criteria. The highest mean value is related to the transit time criteria (*existing influence = 77 %*), followed by reliability (*existing influence = 66 %*). Since every criterion has a mode of one, most respondents agree that the segment has strong influence on freight mode choices. Only 4 respondents selected the *not sure* option. Figure 5 shows the frequencies of each measure.

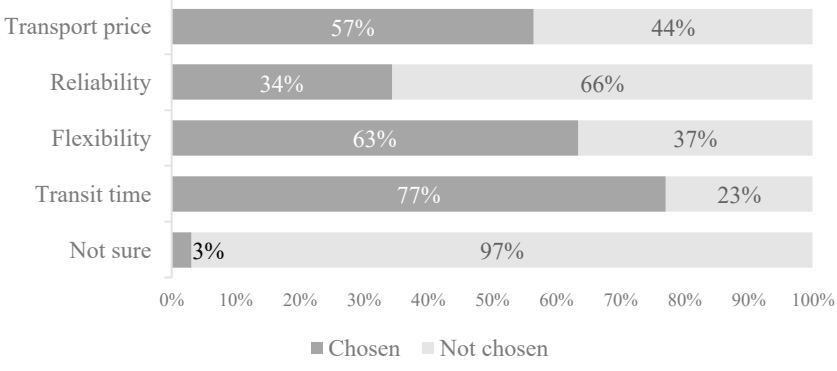

Fig. 5. Shares of mode choice criteria on infrastructural measures

Hypothesis *H5* is not confirmed, as the greatest influence of infrastructure measures, according to the respondents, is on transit time. Transportation price ranks third in terms of frequency distribution, although with a high mean value. In conclusion, the measure seems to be very relevant as it strongly influences the choice of mode in freight transport and thus can lead to a greater change towards a higher modal shift.

The segment of informative measures focuses on the establishment of education and training opportunities for decision makers in freight transport to create a mental shift. Hypothesis *H6* states that this segment will have an impact on the criteria reliability, as strengthening knowledge about eco-friendly transport services might promote changes in the attitudes of decision makers. Respondents expect a strong influence on reliability (*existing influence = 42%*), although still with a mode value of zero, which shows a weak consistent agreement of an impact. The second highest

percentages received flexibility (*existing influence = 36 %*). In addition, the percentages for *not sure* (*34%*) is relatively high, indicating that the measure may not be entirely clear to respondents or that they are not certain about a major impact. Figure 6 represents the percentages of the expected influence.

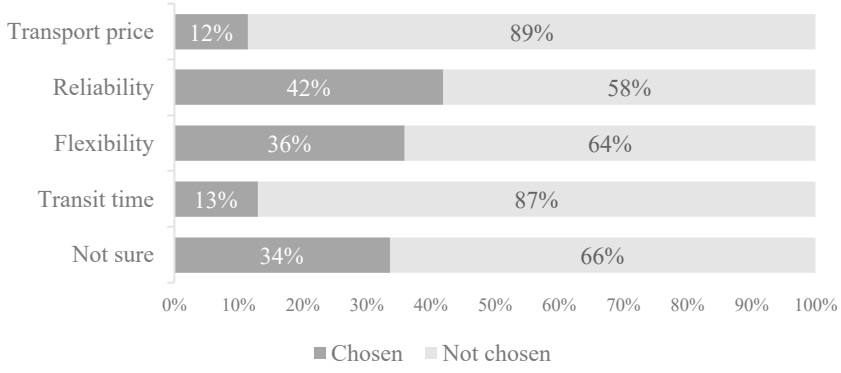

Fig. 6. Shares of mode choice criteria on informative measures

The frequencies clearly visualise that the informative measure segment is considered by respondents to have a rather low impact and given the high proportion of *not sure* responses the measure may indicate some incomprehension. Hypothesis *H6* is not confirmed since the distribution of values regarding an influence of the measure segment are too marginal.

The segment of standardization and harmonization measures analyses through hypothesis *H7* the impact on the mode choice criteria reliability. The modal shift segment mainly deals with measures related to service improvements of eco-friendly transport modes, decreasing multimodal transit-times and a harmonization of the legal framework. The criteria flexibility received the highest mean score (*existing influence = 58%*) while reliability ranked the second highest (*existing influence = 56%*). All three criteria - transit time, flexibility and reliability - received a similar score with only minor differences and a mode of one, meaning that all criteria were perceived as influential by the majority of respondents. This indicates a high impact of the measure segment on freight mode choices, but it is important to state that the mean values are rather low compared to the other modal shift segments. Eight respondents used the *not sure* option in this segment. Figure 7 shows the frequencies for each mode choice criteria.

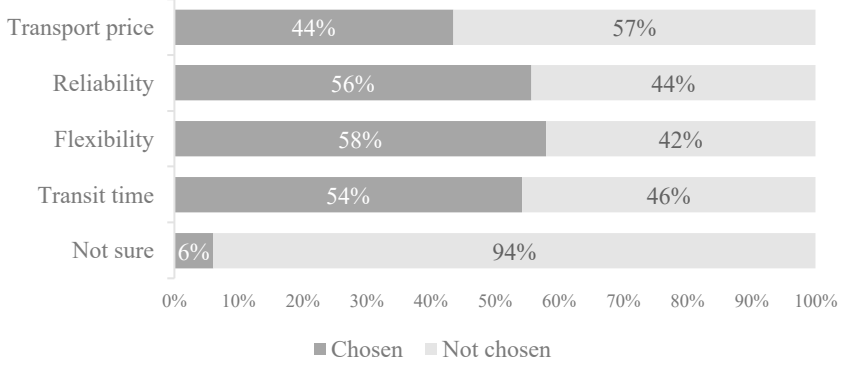

Fig. 7. Shares of mode choice criteria on informative measures

The figure demonstrates that although the three criteria - transit time, flexibility and reliability - show similar values, the average is rather low (no agreement above 60%). Hypothesis *H7*, which states that reliability has the

greatest influence, is not confirmed, although it is second to flexibility, the percentages are too low to detect a strong impact.

The financial incentives segment, which refers to subsidizing eco-friendly modes of transport to increase their deployment, analyzes the impact on the transport price of transport through hypothesis *H8*. Figure 8 visualizes the agreement of the respondents about the influence on transport price (*existing influence = 91 %*). The remaining three criteria - reliability, flexibility and transit time - received a mean value of less than 0.20, indicating a rather low influence on freight mode choices. The *not sure* option was selected by five respondents. According to the results, the largest influence is indeed on the transport price (91%). Therefore, hypothesis *H8* is confirmed.

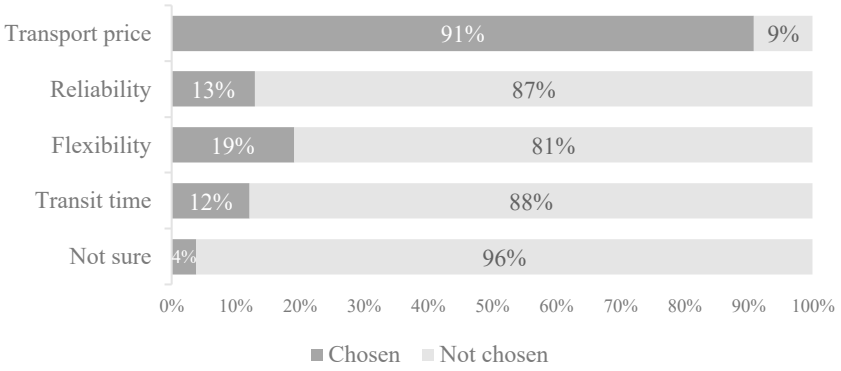

Fig. 8. Shares of mode choice criteria on financial incentives

5.4. Discussion

To summarise the discussion of the results, it is important to point out that freight mode choices should be considered as a joint decision of LSPs and shippers, that the most important criterion for mode choices still seems to be the transport price which is in line with the findings by Zeybek (2019) and Beuthe and Bouffioux (2008). Table 5 summarizes the results of the hypotheses.

Table 5. Overview of hypotheses

ID	Hypothesis	Result
H1	Shippers and LSP agree that both have an equal influence on the modal decision.	Supported
H2	Respondents rank the criterion transport price more important than the criterion reliability when choosing the mode of transport.	Supported
H3	The majority of respondents believe that taxation measures towards modal shift influence the mode choice criteria transport price.	Supported
H4	The majority of respondents believe that regulation measures towards modal shift influence the mode choice criteria flexibility.	Supported
H5	The majority of respondents believe that infrastructural measures towards modal shift influence the mode choice criteria transport price.	Rejected
H6	The majority of respondents believe that informative measures towards modal shift influence the mode choice criteria reliability.	Rejected
H7	The majority of respondents believe that standardization and harmonization measures towards modal shift influence the mode choice criteria reliability.	Rejected
H8	The majority of respondents believe that financial incentive measures towards modal shift influence the mode choice criteria transport price.	Supported

The results showed that transport price criterion is mainly influenced by taxation measures and financial incentives. Taxation measures would increase road freight rates by internalizing external costs, while financial incentives would reduce the transport rates of eco-friendly modes, for ex-ample through subsidies. Nevertheless, the implementation of taxation measures can cause a significant change in the current market and companies need to be prepared for these measures. As Nocera et al. (2018) and Blauwens et al. (2006) concluded, an internalization of external cost would cause strong capacity changes, which need to be planned and considered in advance and could cause a full system change. Nevertheless, it is a very essential measure which could create a fast change, but with a lot of uncertainties. Looking at the other measure influencing strongly the transport price *incentives through subsidies*, Kurtuluş and Çetin (2020) argue that a cost reduction by subsidizing multimodal transports leads to a greater competitiveness but this does not reflect the true cost, and to reach a fundamental modal shift it is important enhance competition through true cost covering. Therefore, to conclude, subsidies rather distort competition and an internalization of external costs to reflect the true cost of transport should be the aim of successful policies. This is in line with the goal of the European Green Deal to establish the "polluter pays" principle (European Commission 2019).

The results of the impact analysis on the reliability criteria showed that infrastructure measures and standardization and harmonization measures appeared to have an impact on it. The hypothesis suggesting that informative measures would have an impact on reliability got detected. However, it should be noted that this does not imply that there is no influence from informative measures on reliability, as most participants chose the option "not sure". This could be explained by the fact that the measure may not be entirely clear. The restricted knowledge on the measure can be explained by the findings of Putz et al. (2018), who demonstrated that knowledge about modal shift and multimodality is highly limited and that active learning such as field trips can trigger knowledge retention. Additionally, Meers and Macharis (2015) argue that a successful modal shift can only achieved through a mental shift of all parties involved. Therefore, awareness raising activities of relevant stakeholders are necessary, even though this measure received a rather low mean value.

According to the respondents, the criterion transit time, which ranks third related to the importance, is mainly influenced by infrastructural measures. A rather high influence of 77% was detected. The infrastructural measure segment deals with measures such as expansion of infrastructure, renovation and modernisation of existing infrastructure and increased capacities among rail and inland waterways. With the adoption of these measures it should be considered that an expansion and renovation of infrastructure is related to a high complexity in infrastructure planning, as highlighted by Otsuka et al. (2017). Additionally, as Behrends (2017) claimed, the expansion of infrastructure comes with a lot of barriers, due to the high cost of planning, implementing and maintaining transport infrastructure. Nevertheless, the results of the survey show that the measures for shippers and LSPs are considered highly essential and necessary for a successful modal shift. Since the implementation of these measures can only take place through the support of political institutions, it is evident that action must be taken here. Additionally, the expansion of the TEN-T network, as promised in the European Green Deal (European Commission 2019), is not sufficient. There is a need to create change at the local level in the development of infrastructure (Blauwens et al. 2006). While European inland waterways are currently underutilized and there is considerable capacity available (CCNR 2022; viadonau 2019), the rail network needs to be expanded rapidly. As Kummer (2010)argued, a modal shift of 15-20% of road freight transport currently leads at the same time to an increase in rail transport by approximately 45-60%. To conclude, infrastructural measures are highly necessary and are building the fundament of a stronger increase in modal shift activities. Local and international authorities need to be aware of the drastic investments required and initiate measures as soon as possible.

Finally, concerning the results of the analysis of the criterion of flexibility of transport mode choice, it is expected that it can be influenced by regulatory measures as well as standardisation and harmonisation measures. The measures related to this segment deal with harmonizing the regulatory framework and shortening intermodal transit times. Pinchasik et al. (2020) remarked that harmonization could strengthen the competitiveness of eco-friendly modes by increasing reliability and flexibility. This is consistent with the results of this paper as an impact was found through the standardization and harmonization area in both mode choice criteria, reliability and flexibility. In terms of shortening intermodal transit times, the literature points out that this would not only increase reliability, but also give freight mode choices decision-makers more flexibility in planning their transport (Pfoser 2021; Blauwens et al. 2006;

Islam et al. 2016). In conclusion, the criteria flexibility should mainly be influenced by standardization and harmonization measures, as these experience a higher acceptance (Pinchasik et al. 2020). In addition, these measure segments indirectly increase the reliability criteria.

6. Conclusions

The increasingly noticeable impact of today's industries on the environment demonstrates that companies need to act now to prevent the consequences of climate change from be-coming irreparable (McKinnon 2015). The objective of this paper was the analysis of modal shift measures which have a significant impact on the criteria used for freight mode choices to increase the use of eco-friendly transport modes such as inland waterways and railroads. The preferences of the decision makers involved, especially shippers and LSP, for the installation of these measures were analysed. The objective was achieved through a comprehensive analysis of the mode choice process and existing modal shift measures using a quantitative investigation among shippers and LSPs to determine their preferences associated with the adoption of these measures. The analysis of the survey showed that modal shift measures were rated positively by the 131 respondents, indicating that mode choice decision makers recognize a need for the adoption of these measures to achieve the objectives set in the *European Green Deal*. It was found that each of the four mode choice criteria (transport price, reliability, transit times and flexibility) can be affected by at least one modal shift segment. Nevertheless, there are differences in the extent of impact. Infrastructure development was identified as the measure that impacts all four mode choice criteria and therefore plays a decisive role. Second among the measures that impact multiple criteria is the standardization and harmonization segment, which had a proven influence on reliability, flexibility, and transit times. Regarding the impact on the transport price, which is the most important criteria in freight mode choices, respondents fully agreed that taxation measures and financial incentives can influence it to a large extent. These measures though received less acceptance by the respondents. The segment with the lowest impact was the informative segment, however, the results indicate that this does not imply that there is no impact from informative measures on reliability, as most respondents selected the "not sure" option, which could be explained by the fact that the measure may not be entirely clear. The findings support the formulation of more precise measures that impact the criteria used in freight mode choices among stakeholders to increase the use of eco-friendly modes.

The main theoretical implication which is provided by this paper is that the most broadly accepted modal shift measure is infrastructure development, which is the only modal shift segment able to influence all four mode choice. This requires further research to identify the most important infrastructure areas and elements that need to be improved. In general, it is important to emphasise that in the future only a combination of all measures will lead to a greater modal shift and that looking at individual measures in isolation is not the most successful way forward. Another element which needs further research is the implementation of taxation measures based on CO2 taxation or external costs. For these measures, policy standards based on scientific research need to be analysed and established.

The main practical implications are that not only policy makers can benefit from the results, but also companies offering eco-friendly transport services can obtain insights in which areas there might be a need for improvement to create more attractive services.

It should be noted that the study is representative only for the selected geographical area and therefore the generalisability in other areas is not guaranteed. However, a future replication of this study in other countries would improve the generalisability of the results, preferably on a larger scale with the inclusion of other European countries. The sample size of 131 respondents can be considered as a limitation when the total sample is divided into individual demographic units and the number of respondents per group. An equal distribution of demographic units in terms of company types and company sizes is given. The distribution of countries as well as the gender distribution is less consistent, with most respondents coming from Austria, followed by Germany.

This study was primarily exploratory in nature and provided a basic understanding of the current state of adoption of various modal shift measures. Given the user-centric approach of our study, which included an analysis of stakeholders' perceived expectations regarding the influence of policies on mode choice factors, it is advisable that future research explore the relationships between these policies and mode choice criteria through more sophisticated quantitative impact simulation analyses. Beyond that, the results support previous research on freight mode choices and modal shift research. Future research should focus more on how these identified measures can be installed and

addressed at different levels of policy making, at a country or EU level. Thus, it is suggested that the adjustment of freight mode choices through policy measures is a valuable subject for future research, and there is still extensive research needed to explore the most appropriate way for a successful modal shift.

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Appendix A. Questionnaire

Table 6. Survey overview of items, questions and evaluation codes

Code	Question	Evaluation
	Demographic section (D)	
Gender	Gender	(1) female (2) male (3) diverse
Country	Please assign your company to the right type	(1) Austria (2) Germany (3) Benelux
Company type	Please assign your company to the right type	(1) Shipper (2) LSP
Company size	How many people are employed in your company?	(1) < 10 employees (2) < 50 employees (3) < 250 employees (4) ≥ 250 employees
	Mode choice section (M)	
Decision maker	When choosing a mode of transport how strong is the influence of shippers?	5-point Likert scale (1) no influence (5) full influence
Mode choice criteria	Please rank the importance of the following criteria when choosing the right mode of transport: *Transport price / Reliability / Flexibility / Transit time*	7-point Likert scale (1) no importance (7) high importance
	Impact analysis section (IM)	
Impact mode choice	*Taxation measure > Transport price, Reliability, Flexibility, Transit time, not sure* *Regulation measures > Transport price, Reliability, Flexibility, Transit time, not sure* *Infrastructural measures > Transport price, Reliability, Flexibility, Transit time, not sure* *Informative measures > Transport price, Reliability, Flexibility, Transit time, not sure* *Standardization and harmonization measures >> Transport price, Reliability, Flexibility, Transit time, not sure* *Financial measures > Transport price, Reliability, Flexibility, Transit time, not sure*	0 = chosen 1 = not chosen

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