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Modal shift from road haulage to short sea shipping: a systematic literature review and research directions

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ABSTRACT

Modal shift from road haulage to short sea shipping (SSS) has been advocated by authorities and researchers for more than two decades. This paper provides a review of literature on modal shift and pinpoints paths for future research on topics in six categories: (1) factors influencing SSS competitiveness, (2) the policy-oriented perspective, (3) environmental legislation, (4) SSS performance, (5) port characteristics, and (6) the multi-agent perspective. In particular, we propose first, in evaluating the performance of SSS versus road haulage in different trade corridors, three performance-related dimensions – the economic dimension (e.g. external costs), the environmental dimension, and the dimension of service quality – should be considered. Second, researchers should use rich, real-world, numerical data and operational research techniques to identify the relative importance of individual drivers and barriers for a modal shift from road haulage to SSS. Third proposed direction is related to assessing which groups of actors certain policies should target. In doing so, researchers should extend their policy-related focus beyond the European Union, which has long encompassed the major geopolitical scope of research on the modal shift. Fourth, to moderate the adverse impact of environmental legislation on SSS, strategic solutions need to be identified. Fifth, we also suggest that the influence of contingencies, particularly port strikes and cyberattacks, on SSS operations and approaches for managing them should be investigated. Sixth, the economic and financial advantages of coordination and alliance for each transport chain agent need to be evaluated.

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KEYWORDS
Modal shift; freight transport; road haulage; short sea shipping (SSS); literature review; research directions

1. Introduction

During the past few decades, along with unprecedented growth in global trade, the demand for reliable, flexible, door-to-door, and cost-efficient freight transport has accelerated across the world (Stank & Goldsby, 2000). In 2016, total goods transport

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activities in the EU-28, for instance, reached 3661 billion tonne-kilometres, and road haulage (i.e. trucking) accounted for nearly half of the total freight transport market share (EC, 2018).

However, road haulage is often characterised as causing environmental and societal problems in terms of negative externalities, including highway congestion and longer wait times, air pollution, climate change, traffic accidents, noise, infrastructure damage, and high energy consumption (Chang, Lee, Kim, & Shin, 2010). To overcome those road-related negative externalities, an instrumental measure suggested by researchers and the European Commission is a modal shift to less polluting modes, such as waterborne transport, for example short sea shipping (SSS) (Woodburn & Whiteing, 2014), especially in situations where waterborne transport is cost-efficient (McKinnon, 2008). Despite policies to promote the competitiveness or use of SSS in the EU 28, the share of road haulage in terms of total cargo volumes transported has increased from 45.3% in 1995–49.3% in 2016, whereas the share of SSS has slightly declined from 32.7% to 32.3% in those for the respective years (EC, 2018).

Since becoming a major item on the political agenda in the 1990s, the topic of modal shift has attracted considerable attention from researchers, who have mostly focused on shifting from unimodal road haulage to intermodal rail transport, as reported in the review by Bontekoning, Macharis, and Trip (2004). Other reviews have addressed topics such as modal shift from car to active transport (Scheepers et al., 2014) and green ports in maritime logistics (Davarzani, Fahimnia, Bell, & Sarkis, 2016). On top of that, Meixell and Norbis (2008) and Flodén, Bärthel, and Sorkina (2017) have reviewed scientific and grey literature on choice of freight transport mode from different perspectives. Compared to those earlier reviews, however, our study adds value by reviewing the relevant literature and providing avenues for future research on modal shifts focusing on road haulage and SSS.

In the remainder of this paper, Section 2 presents the methods used to identify literature for our review. The results, including the key features of articles reviewed and research categories, appear in Section 3. We conclude the paper by providing a summary of findings and directions for future research in Section 4.

2. Method

Literature reviews provide a comprehensive consolidation and evaluation of literature in a specific field of knowledge, as well as identify gaps in the field's body of knowledge that should be filled to further develop the field (Tranfield, Denyer, & Smart, 2003; Van Wee & Banister, 2016). In our systematic review, we followed the protocols referred to by Tranfield et al. (2003), Petticrew and Roberts (2006), Bossle, Dutra de Barcellos, Vieira, and Sauvée (2016), and Van Wee and Banister (2016). In particular, we followed Tranfield et al. (2003) rigid, scientific process proposed for literature searches and assessments of information retrieved. The research protocol followed appears in Figure 1.

2.1. The planning phase: refining the inclusion and exclusion criteria

Identifying relevant keywords for the literature search was a fundamental step in the planning phase of our study. In line with Davarzani et al. (2016), an iterative process was

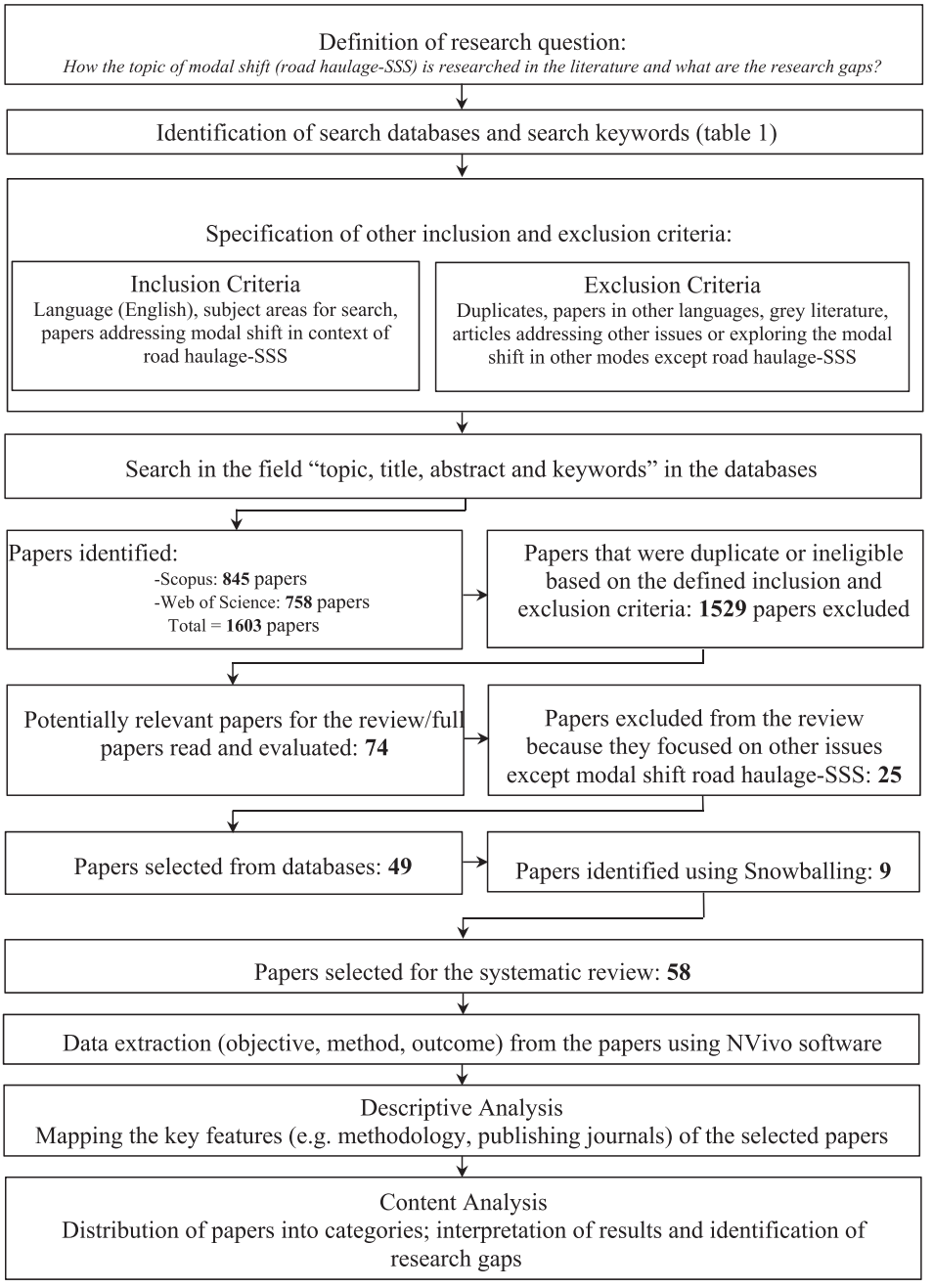

Figure 1. Steps followed in the systematic literature review. Source: Adapted from Tranfield et al. (2003), Petticrew and Roberts (2006), Bossle et al. (2016), and Van Wee and Banister (2016).

followed to design an appropriate structure for using keywords in the literature search. The process comprised multiple steps: determining a preliminary set of keywords and a search structure, examining articles and journals found in order to confirm appropriate coverage, updating keywords to exclude irrelevant articles, research, and subject fields,

and updating the keyword structure accordingly. The four-level structure of the literature search using keywords (Davarzani et al., 2016) and Boolean operators appears in Table 1. The use of AND between two keywords requires both to be in each article returned. The use of OR means that either or both keywords will be in the returned articles. The use of AND NOT means that keywords before AND NOT are searched in the database, but articles containing the keywords after AND NOT are removed from the results. The use of AND NOT reduces number of articles returned and is done to get an amount of articles feasible to review, but may risk eliminate a few relevant articles. Therefore, to reduce the risk of missing any important article for this review, a forward and backward snowballing approach referred by Van Wee and Banister (2016) is deployed. Snowballing took the departure from five literature review papers, see, (Brooks & Frost, 2004; Medda & Trujillo, 2010; Paixao & Marlow, 2002; Paixao & Marlow, 2007; Suárez-Alemán, 2016).

Two databases – Web of Science and Scopus – were accessed to search for articles, both of which are endorsed as good sources of peer-reviewed articles in the social sciences, especially literature on business, logistics, and supply chains (Chicksand, Watson, Walker, Radnor, & Johnston, 2012; Dahlander & Gann, 2010).

2.2. The search phase: conducting and reporting the review

A comprehensive search for peer-reviewed articles was conducted in May 2017. To achieve broad coverage of relevant articles and reduce the risk of missing important articles, the search was mostly performed in the "topic" and "title, abstract, keywords" fields of both databases.

The search resulted in 845 articles from Scopus and 758 articles from Web of Science. To assess the relevance of articles based on the inclusion and exclusion criteria and to remove any duplicates, the titles and abstracts of all were read. As a result, 74 articles were retained and 1529 others were excluded, because they either did not meet the inclusion criteria or were duplicates. After the 74 articles retained were thoroughly read, an additional 25 articles were excluded, because they examined modal shifts in the context of other transport modes and did not focus on comparing SSS and road haulage. Ultimately, 49 articles remained from database search. In the existing literature several key words are interchangeably used to address the modal shift topic, therefore, it might not be feasible to

Table 1. Keywords used in the literature search.

Keywords
Four-level search framework
Short sea OR Shortsea OR coastal OR cargo OR freight OR truck OR road OR RoRo OR RoPax OR container OR sea OR intermodal OR multimodal OR combined
AND
Shipping OR transport OR service OR transportation OR movement OR transshipment OR forwarding, OR haulage OR delivery
AND
Modal shift OR Mode shift OR shift in transport mode OR modal (mode) switch OR modal diversion OR modal substitution OR modal split OR alternative mode OR mode competition OR competing mode OR mode competitiveness OR competitor
AND NOT
Inland shipping OR inland waterways OR barge shipping OR river shipping OR lake shipping OR hinterland OR urban freight OR modal shift from road to rail freight OR modal shift from air to land modes OR modal shift from private vehicles to walking, cycling, and public transport

argue that all the relevant papers have been found using databases. Thus, to address this problem the snowballing approach proposed by Van Wee and Banister (2016) was used and an additional nine articles were found by checking the reference section of the published scientific papers. Finally, 58 papers are included in the final analysis.

We used NVivo qualitative data analysis software to extract information from each article, including the name(s) of the author(s), year of publication, journal of publication, geographical area studied, chief contributions, and methodology employed.

3. Results

The data collected via the systematic review were analysed in depth in order to map the selected literature in descriptive analysis, categorise the articles, gain insights into the concepts on which they focus, and highlight gaps in research on the various topics. In writing this section, we have followed earlier reviews on transportation by Centobelli, Cerchione, and Esposito (2017) and Bontekoning et al. (2004).

3.1. Descriptive analysis

This section reviews the four basic features of the articles, all of which address modal shifts with a focus on the shift from road haulage to SSS:

(1) Distribution by journal of publication;
(2) Distribution by year of publication;
(3) Distribution by geographical area in focus; and
(4) Distribution by methodology.

3.1.1. Distribution by journal of publication

As shown in Table 2, 58 articles addressing the modal shift from road haulage to SSS have appeared in 21 scientific journals. Twelve journals on transportation published 27 of the articles (46%). Also, among the most prolific in work on the topic, journals addressing maritime transport published 27 of the articles (46%), of which *Maritime Policy and Management* contributed the most (i.e. 20 papers). The remaining four papers (7%) appeared in four different journals.

3.1.2. Distribution by year of publication

Research on the modal shift from road haulage to SSS has increased in recent years (Figure 2). Whereas 59% of the articles (i.e. 34 articles) were published in the 7-year period from 2011 to 2017, only 41% (i.e. 24 articles) were published during the 15-year period from 1996 to 2010.

3.1.3. Distribution by geographical area of focus

Research on the modal shift from road haulage to SSS has primarily focused on Europe (45 papers), as detailed in Table 3. Only a few papers have addressed the potential for modal shift in the context of other continents, including North America (i.e. six papers), Asia (i.e. two papers), Australia (i.e. four papers), and South America (i.e. one paper). The reason for

Table 2. Journals of publication and number of articles contributed.

Journal	Number of articles
Transportation	
Transport Reviews	6
Transportation Research Record	3
International Journal of Shipping and Transport Logistics	3
Transportation Research Part D: Transport and Environment	3
Transportation Research Part E: Logistics and Transportation Review	2
Transportation Research Part A: Policy and Practice	2
Transport Policy	2
Journal of Transport Geography	2
European Transport Research Review	1
European Journal of Transport and Infrastructure Research	1
International Journal of Transport Economics	1
Transportation Letters	1
Maritime transport	
Maritime Policy and Management	20
Maritime Economics and Logistics	4
Journal of Maritime Research	1
Marine Policy	1
WMU Journal of Maritime Affairs	1
Miscellaneous	
Sustainability	1
British Food Journal	1
Carbon Management	1
Transport	1
Total	**58**

the predominant focus on Europe may be that several EU countries have less intra-European trade, fewer regulatory barriers, and better connections via waterways than countries on other continents. Moreover, the European Union has enacted various policies to promote the modal shift in order to mitigate the rise of road-related negative externalities.

The affiliated institutions of contributing authors were also extracted and their host cities ascertained. Using such data in Tableau Desktop software, the geographical locations of institutions that have contributed to research on modal shift were mapped, as shown in Figure 3.

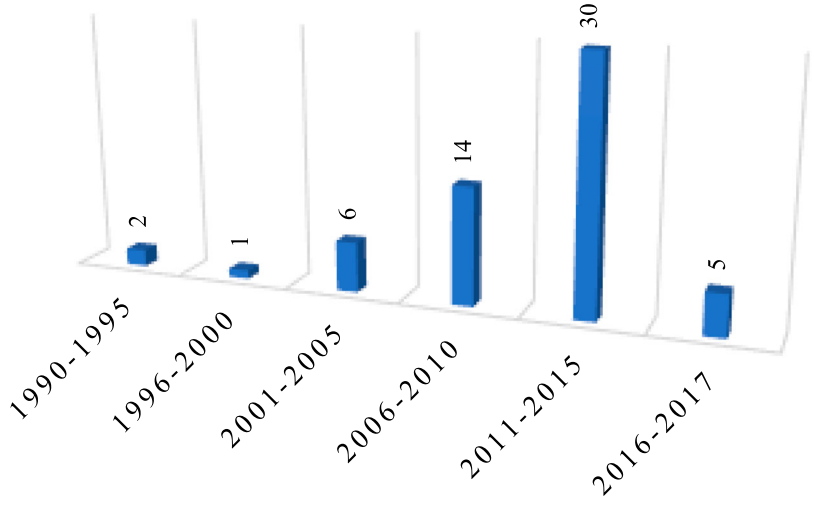

Figure 2. Distribution of articles reviewed by year of publication, 1990–2017.

Table 3. Authors, methods, and regions or countries of focus.

Author(s) and year of publication	Method	Region or country of focus*
Literature review		
Paixao and Marlow (2002)	Literature research	Europe
Brooks and Frost (2004)	Literature research	Canada
Sanchez and Wilmsmeier (2005)	Literature research	Central America
Paixao and Marlow (2007)	Literature research	Europe
Baird (2007)	Literature research	Europe
Medda and Trujillo (2010)	Literature research	Europe
Baindur and Viegas (2011)	Literature research	Europe
Douet and Cappuccilli (2011)	Literature research	Europe
Aperte and Baird (2013)	Literature research	Europe
Suárez-Alemán (2016)	Literature research	Europe
Mathematical models		
Ng (2009)	Integer programming	Europe
Chang et al. (2010)	Linear programming model	South Korea
Tsamboulas, Moraiti, and Vlahogianni (2010)	Probabilistic model	Europe
Holmgren, Nikopoulou, Ramstedt, and Woxenius (2014)	TAPAS simulation model	Europe
Suárez-Alemán and Hernandez (2014)	Non-linear programming	Europe
Juste and Ghiara (2015)	Gravity simulation model	Europe
Rodrigues et al. (2015)	Simulation model	Europe
Survey		
Paixao and Marlow (2005)	Survey	Europe
Paixao and Marlow (2009)	Survey	Europe
Feo, Espino, and García (2011)	Survey	Europe
Morales-Fusco, Saurí, and De Melo (2013)	Survey	Europe
Case study		
Hjelle (2010)	Case Study	Europe
Hjelle (2011)	Case Study	Europe
Corbett et al. (2012)	Case study	USA
Hjelle (2014)	Case study	Europe
Bergqvist, Turesson, and Weddmark (2015)	Case study	Europe
Galati et al. (2016)	Case Study	Europe
Mixed methods		
D'Este and Meyrick (1992)	Interviews and stated preference survey	Australia
D'Este (1992)	Literature research and stated preference survey	Australia
Becker, Burgess, and Henstra (2004)	Case study, literature research and interviews	Europe
Bergantino and Bolis (2008)	Interviews and adaptive stated preference technique	Europe
Brooks and Trifts (2008)	Survey and discrete choice methods	Canada
Perakis and Denisis (2008)	Literature research and SWOT analysis	USA
Garcia-Menendez and Feo-Valero (2009)	Interviews and disaggregate behavioural model	Europe
Lee, Hu, and Chen (2010)	External cost models and Interviews	Taiwan
Bendall and Brooks (2011)	Literature research and interviews	Australia, Canada, USA
Notteboom (2011)	Survey and comparative price analysis	Europe
Puckett, Hensher, Brooks, and Trifts (2011)	Survey and generalised mixed logit model	Canada, USA
Baindur and Viegas (2012)	Case study, interviews and simulation model	Europe
Brooks, Puckett, Hensher, and Sammons (2012)	Survey and stated choice experiment	Australia
Nealer, Matthews, and Hendrickson (2012)	Input–output analysis and life-cycle assessment	USA
Perez-Mesaa, Galdeano-Gomez, and Salinas-Andujar (2012)	Survey and AHP technique	Europe
Sambracos and Maniati (2012)	Case study and generalised cost methods	Europe
Woxenius (2012)	Case study, literature research and interviews	Europe
López-Navarro (2013)	Survey and partial least squares (PLS) analysis	Europe

(*Continued*)

Table 3. Continued.

Author(s) and year of publication	Method	Region or country of focus*
Panagakos, Stamatopoulou, and Psaraftis (2014)	Case study and modal split model	Europe
Tsamboulas, Chiappetta, Moraiti, and Karousos (2015a)	Case study and cost benefit analysis (CBA)	Europe
Suárez-Alemán, Campos, and Jiménez (2015a)	Case study and generalised cost method	Europe
Tsamboulas, Lekka, and Rentziou (2015b)	Case study, four-step model and CBA	Europe
Zis and Psaraftis (2017)	Case study, modal split model	Europe
Other methods		
Baird (1999)	Interviews	Europe, Japan
Saldanha and Gray (2002)	Delphi-type survey	Europe
Tsamboulas, Vrenken, and Lekka (2007)	Macro-scan approach	Europe
Morales-Fusco, Saurí, and Lago (2012)	Cost model	Europe
Martell, Martínez, and Martínez de Oses (2013)	DETCCM algorithm	Europe
López-Navarro (2014)	Marco Polo calculator's coefficients	Europe
Kotowska (2016)	External cost model	Europe
Suárez-Alemán, Trujillo, and Medda (2015b)	Theoretical model	Europe

*Country or region to which the research applies.

The size of the red circles in Figure 3 visualises the relative contribution of each institution. The figure also summarises the number of first-author contributions from each country. Over all, research on the modal shift from road haulage to SSS has been conducted mostly in Europe (i.e. 45 papers), followed by North America (i.e. six papers), whereas work from Africa, Oceania, and South America has rarely appeared.

3.1.4. Distribution by research method used

The articles showcase a variety of research methods used (Table 3, column 2). The authors of 10 articles conducted literature reviews to summarise policies and problems related to the modal shift, whereas the authors of 11 other articles used surveys and mathematical

Figure 3. Distribution of the geographical location of the affiliated institutions of the authors.

Number of contributions by country: Spain including Canary Islands (13); Greece (6); the United Kingdom (5); Australia and the United States (4); Canada, Norway, Portugal, and Sweden (3 each) France, India, and Italy (2 each); and Belgium, Chile, China, Denmark, South Korea, the Netherlands, Poland, and Taiwan (1 each).

models to analyse competition between road haulage and SSS in particular trade corridors. The authors of six articles employed case studies to qualitatively explore the modal shift, and those of 23 others used mixed methods by combining case studies or surveys with other quantitative and qualitative methods to ensure a methodologically balanced approach. Other methods, including interviews and Delphi surveys, were deployed by authors in eight articles.

3.2. Content analysis

In the literature reviewed, six research categories based on topics and problems covered were identified: (C1) factors influencing SSS competitiveness, (C2) the policy-oriented perspective, (C3) environmental legislation, (C4) SSS performance, (C5) port characteristics, and (C6) the multi-agent perspective. Some of the articles were classified into two to three categories due to their broad scopes.

3.2.1. Factors influencing SSS competitiveness (C1)

Factors influencing the competitiveness of SSS versus road haulage were identified and divided into two sub-categories:

(1) Drivers: Enablers or determinants (e.g. strengths or advantages of SSS compared to unimodal trucking and other conditions) that stimulate the use of SSS. Nineteen drivers identified were classified into six groups (D1–6), as shown in Table 4.
(2) Barriers: Impediments or factors (e.g. issues, limitations, or weaknesses of SSS) that hinder the use of SSS. Twenty-four barriers, classified into seven groups (B1–7), are listed in Table 5.

Research gaps. Because most articles have provided rather descriptive analyses, literature on the modal shift from road haulage to SSS has rarely offered empirical evidence for the majority of the reported drivers and barriers. For example, the reduced hours of trucking services and the imposition of increased tolls and eco-taxes on trucking have been mentioned as important regulatory drivers of the modal shift to SSS. However, the literature has not provided any evidence for determining in which corridors those drivers could be useful or evidence of the degree of modal shift generated by the drivers. Therefore, we believe that more empirical research using real-world data regarding the impact of drivers and barriers on the modal shift, derived from market reports, surveys, interviews of stakeholders involved, and other sources, is needed. Conducting large surveys amongst suppliers of SSS, as well as of current and potential SSS customers, to verify and weigh those barriers and enablers would be a good start for future research. Multi-criteria analysis could also be useful to interpret the results of such surveys in greater detail.

3.2.2. The policy-oriented perspective (C2)

Various types of policy initiatives, both economic and regulatory as well as both implemented and theoretical, aimed at encouraging the modal shift to SSS from road haulage were addressed in nine articles.

Table 4. Articles highlighting drivers of the competitiveness of short sea shipping (SSS).

	Driver groups and drivers									
	D1. Financial			D2. Capacity					D3. Operational	
Author(s) and year of publication	Lower required investment in infrastructure	Cost-effectiveness	Economies of scale	Underused shipping capacity	Availability of sufficiently long sea lanes	Capacity to carry large industrial unit loads	SSS as a new alternative	Easy to expand transportation network capacity	High energy efficiency	Flexible operating hours
Baird (1999)	•									
Paixao and Marlow (2002)	•	•	•	•	•	•			•	•
Brooks and Frost (2004)				•						
Sanchez and Wilmsmeier (2005)	•									
Perakis and Denisis (2008)	•		•					•	•	
Medda and Trujillo (2010)		•					•			•
Bendall and Brooks (2011)					•					
Morales-Fusco et al. (2013)			•	•						
Total	4	2	3	3	2	1	1	1	2	2

Author(s) and year of publication	Driver groups and drivers								
	D4. External					D5. Regulatory			D6. Other
	Reduced air pollution	Fewer accidents	Less congestion	Fewer noise emissions	Higher safety in dangerous goods transport	Imposition of eco-taxes and carbon taxes on truck fuels	Imposition of more road tolls	Reduced hours of service by truck drivers	Alliances with trucking industry and port authorities
Baird (1999)			•						•
Paixao and Marlow (2002)	•	•	•	•	•	•		•	•
Brooks and Frost (2004)	•		•						
Sanchez and Wilmsmeier (2005)	•					•	•		•
Perakis and Denisis (2008)	•		•	•	•				•
Medda and Trujillo (2010)	•		•	•					
Bendall and Brooks (2011)	•		•			•	•	•	•
Morales-Fusco et al. (2013)									
Total	6	1	6	3	2	3	2	2	5

Table 5. Articles highlighting barriers to the modal shift from road haulage to intermodal short sea shipping (SSS).

	Barrier groups and barriers											
	B1. Service quality					B2. Financial		B3. Technical				
Author(s) and year of publication	Longer lead times at ports and in transit and slower speeds	Lower reliability	Lower frequency	Additional cargo-handling costs	Capital intensity of SSS industry	Additional inventory costs for shippers	High labour costs	Incompatibility of equipment and ICT systems	Complicated customs clearance rules	Absence of integrated management systems	Lack of robust strategy in SSS firms	Lack of innovation and R&D activities
Baird (1999)	•											
Paixao and Marlow (2002)	•	•	•	•		•		•		•	•	•
Saldanha and Gray (2002)	•		•		•			•		•	•	•
Brooks and Frost (2004)	•			•								
Paixao and Marlow (2005)	•	•							•		•	•
Sanchez and Wilmsmeier (2005)								•				
Perakis and Denisis (2008)	•	•		•				•		•		
Medda and Trujillo (2010)	•		•			•						
Bendall and Brooks (2011)		•		•			•		•			
Baindur and Viegas (2011)					•			•				
Martell et al. (2013)	•								•			
Morales-Fusco et al. (2013)	•											
Total	9	4	3	4	2	2	1	5	3	3	3	3

Author(s) and year of publication	Barrier groups and barriers											
	B4. Communication				B5. Service and market				B6. Regulatory			B7. Administrative
	Poor industry image	Poor marketing activities by SS firms	Weak communication by SSS firms	Insufficient information available to SSS users	Poor port–hinterland connectivity	Lack of SSS integration into door-to-door transport chain	Shortage of RoRo vessels in the spot market	Volatility of transport demand	Construction of road infrastructure for trucking	Inconsistent policies	Imposition of taxes in SSS sector	Complex documentary and administrative procedures
Baird (1999)									•			
Paixao and Marlow (2002)	•	•	•	•	•	•						•
Saldanha and Gray (2002)		•		•	•	•						
Brooks and Frost (2004)								•		•		
Paixao and Marlow (2005)	•											
Sanchez and Wilmsmeier (2005)		•		•	•					•		
Perakis and Denisis (2008)	•									•	•	
Medda and Trujillo (2010)	•				•	•						•
Bendall and Brooks (2011)											•	
Baindur and Viegas (2011)							•	•		•		
Martell et al. (2013)												•
Morales-Fusco et al. (2013)												
Total	4	3	1	3	4	3	1	2	1	4	2	3

As a specific type of SSS, Motorways of the Seas (MoS), defined and promoted by the European Union, operate in four maritime corridors: the Baltic Sea, Western Europe, South-East Europe, and South-West Europe defined and promoted by the EU. Baird (2007) illustrated how different seaways, not only MoS, have developed and concluded that though a modal shift can be achieved with innovative carriers (e.g. new RoRo ships) and under different environmental circumstances, such measures often need to be supported by policies. Aperte and Baird (2013) investigated MoS policy in terms of how it aligns with other maritime polices and the European transport policy, as well as how it functions within the Trans-European Transport Network. They argued that MoS have had little effect in general, for reasons including limited support from policies. Baindur and Viegas (2011) identified critical factors for establishing MoS projects, including economic policies, (e.g. the internalisation of external costs) and regulatory policies (e.g. various measures to restrict or /discourage road freight).

Douet and Cappuccilli (2011) acknowledged that the European Union has promoted the modal shift from road haulage to SSS, albeit with disappointing results. They argued that such dismal outcomes could be explained, for example, by the fact that the European Union has mis-adapted policies promoting the shift, largely due to problems with inexact definitions of *SSS* that do not correspond to their programmes aimed at supporting the shift. For the benefit of policymakers, Brooks and Frost (2004) investigated key trends in SSS from a Canadian perspective in terms of limitations and impediments to increasing the use of SSS in Canada and across the US–Canadian border. Policy-hampering factors included the requirement that domestic traffic has to bear a Canadian flag, complicated tax issues, and duties on foreign-built ships. In response, they suggested that different policy measures, including the US Clean Air Act or Kyoto credit programme, could favour the modal shift to SSS.

In three articles, authors have modelled the effects of different policy measures. Among them, Garcia-Menendez and Feo-Valero (2009) found that, along with traditional determinants in terms of cost and transit time, additional policy-related variables may be of equal importance: the use of INCOTERMS, overland distance, relative value added, shipment size, and company type. Tsamboulas et al. (2007), who assessed the potential of policy measures to affect the modal shift, revealed that policy measures such as a directive for working hours and the internalisation of external costs have strengthened the competitiveness of sea versus road transport. Later, Tsamboulas et al. (2015a) showed that the implementation of the Ecobonus afforded significant cost savings and benefits to society in general, as well as exceptional returns on investments for the Italian government. Last, Becker et al. (2004) analysed whether SSS could be more successful with high-speed vessels but concluded that policies that promote high-speed vessels are neither in place nor should be, because the market would produce such solutions.

Research gaps. Although policy plays an important part in promoting the modal shift to SSS, the results of policies thus far have been somewhat disappointing. Aperte and Baird (2013) argued that seaway infrastructure equivalent to that of roadways is not the waterway but the deck of the ship and that adjusting policies to incorporate such a view could level the playing field between sea and land to promote a modal shift. In that sense, policies for road transport cannot easily be treated the same as those for sea transport. In response, researchers should address redefining policy measures that accommodate the

unique characteristics of sea transport, for example, to encourage a modal shift to the sea that would complement the predominant shift from the road.

The Italian Ecobonus system is directed towards transport buyers, which is a strength according to Tsamboulas et al. (2015a). In contrast, Suárez-Alemán (2016) critically reviewed the SSS transport policy in the European Union, argued that poor results may be partly attributed to the fact that policies principally target transport buyers who shift goods from road to the sea and not how to make SSS more attractive by increasing efficiency, especially at ports. Therefore, important directions for future research are to more thoroughly compare how value for money is best attained and for which types of actors. A thorough analysis also needs to be made of European projects implemented in different countries. Such an analysis should include both qualitative methods (e.g. interviews with all important stakeholders in the cases) and quantitative ones (e.g. analyses of all possible metrics from the cases) and be executed via a case study. Moreover, relating inputs to outputs and understanding the accompanying processes are essential steps to substantiating conclusions to guide SSS-oriented policymaking.

3.2.3. Environmental legislation (C3)

The environmental friendliness of SSS is an essential driver of modal shift, as related in the discussion of category C1 in Section 3.2.1. However, increased sulphur emissions caused by overall shipping activities have prompted the implementation of a sulphur emissions regulation (i.e. MARPOL Annex VI) for vessels operating in the North Sea and Baltic Sea Sulfur Emission Control Areas (SECAs). In six articles, scholars estimated the potential impact of the regulation on the competitiveness of SSS, which can theoretically be worsened by higher compliance costs.

Notteboom (2011) conducted a detailed comparative cost and price analysis to evaluate competition between intermodal SSS and unimodal trucking for 30 routes connected to the North European SECA. The findings of that study indicate that using expensive marine gas oil (MGO) as the preferred SECA-compliant solution could substantially increase operating costs and, in turn, trigger modal backshift from SSS to unimodal trucking. Moreover, Bergqvist et al. (2015) reached similar conclusions for the Swedish forest industry. Panagakos et al. (2014) investigated the impact of the prospective designation of the Mediterranean Sea as a SECA and predicted that applying such a regulation in the Mediterranean would favour trucking over intermodal SSS only for clothing shipments between Greece, Italy, and Austria. By contrast, Holmgren et al. (2014) found that high-value containerised cargo shipments between Lithuania and the British Midlands are insensitive to sulphur regulations. Zis and Psaraftis (2017) showed that a recent decline in fuel prices to a certain extent mitigated the detrimental impact of the regulation on the modal shift but also that any potential increase in fuel prices would reverse the trend. However, Woxenius (2012) illustrated that the adoption of slow steaming as a strategy to deal with the sulphur regulation in the RoRo vessel segment operating in South Baltic Sea region may not jeopardise the competitiveness of RoRo shipping in the region as slow steaming reduces the vessel fuel consumption and thus lowers the operating cost. Overall, the findings suggest that environmental regulations (i.e. SECAs) impair the competitiveness of SSS.

Research gaps. Arguably, the above-cited studies suggest a consensus that the magnitude of the impact of sulphur regulations on the modal shift depends on the cost of

compliant solutions (e.g. MGO price), route length, and the value of the cargo being shipped. Cost and price analyses have generally been based on the price of MGO as a compliant solution, whereas other compliant measures such as scrubbers and liquified natural gas have been overlooked in calculations. In addition, we observed that European infrastructure and electric vehicle charging systems (e.g. Eurovignette, a regulation for the trucking industry) have also been neglected in cost calculations, except by Holmgren et al. (2014) and Notteboom (2011). Moreover, IMO's CO_2 reduction targets and upcoming global sulphur limits of 2020, due to expensive compliance measures, may further increase freight rates for sea transport and eventually prompt modal backshift to road haulage in Europe. Such trends require more quantitative research, particularly with models that link volumes to costs and emissions, to clarify the real impact of current and forthcoming regulations on the modal shift from road haulage to SSS. Furthermore, because researchers have revealed a risk of modal backshift due to SECAs, an important path for future research is to investigate the effects of possible policy strategies to mitigate SECA's adverse impact on SSS. In particular, the possible measures of providing subsidies to SSS or imposing taxes on road haulage provide opportunities for future research.

Another overlooked aspect of the modal shift from road transport to SSS is that regulatory pressure stimulates innovation (Bossle et al., 2016) and that such innovations promote better environmental and business performance (Porter & van der Linde, 1995). Thus, empirical studies involving the analysis of the qualitative and quantitative effects of innovations in the context of environmental legislation affecting the maritime sector is a relevant direction for future research. The results of such research could stimulate SSS firms to invest more in innovations, which could at once support their compliance with environmental regulations and improve their business performance.

3.2.4. SSS performance (C4)

Addressed in 26 articles, the performance of intermodal SSS versus that of door-to-door road haulage ranks among the most extensively studied topics in the literature reviewed and has been approached in terms of three types of performance (Table 6):

(1) Economic performance, by calculating and comparing types of generalised and external costs for road haulage and intermodal SSS services in various trade corridors;
(2) Service quality performance, by comparing the performance of both modes in terms of quantified time-related attributes of service quality; and
(3) Environmental performance, by calculating and comparing environmental pollutants such as sulphur oxides (SOx), nitrogen oxides (NOx), particulate matter (PM_4), and carbon dioxides (CO_2) emitted from both transport modes.

Economic performance. The primary objective of studies on the relative economic performance of intermodal SSS versus road haulage has been to assess the cost-competitiveness of prospective intermodal SSS services against road haulage. Ng (2009) simulated and compared the generalised costs (e.g. monetary costs) and costs related to service quality (e.g. time costs) of SSS to those of road haulage for the transportation of containerised cargo shipments between the Baltic region and Western Europe. Among the results, SSS was more competitive only in certain regions and at certain ports, which suggests that policymakers should focus on those regions by providing infrastructure and other facilities

Table 6. Articles addressing the relative performance of intermodal SSS and road haulage.

Author(s) and year of publication	Economic performance	Service quality performance	Environmental performance
D'Este and Meyrick (1992)		•	
D'Este (1992)		•	
Bergantino and Bolis (2008)		•	
Brooks and Trifts (2008)		•	
Ng (2009)	•	•	
Chang et al. (2010)	•	•	
Hjelle (2010)			•
Lee et al. (2010)	•		
Feo et al. (2011)	•	•	
Hjelle (2011)			•
Puckett et al. (2011)		•	
Brooks et al. (2012)		•	
Corbett et al. (2012)			•
Morales-Fusco et al. (2012)	•	•	
Nealer et al. (2012)			•
Perez-Mesaa et al. (2012)	•	•	
Sambracos and Maniati (2012)		•	
Martell et al. (2013)	•	•	
Hjelle (2014)			•
López-Navarro (2014)	•		
Juste and Ghiara (2015)	•	•	
Rodrigues et al. (2015)			•
Suárez-Alemán et al. (2015a)	•	•	
Tsamboulas et al. (2015b)	•	•	
Galati et al. (2016)	•	•	
Kotowska (2016)	•		
Total	13	17	6

to achieve the modal shift to SSS. Feo et al. (2011) and Morales-Fusco et al. (2012) conducted similar studies for trade corridors in the Mediterranean region. The added value of those studies is that their analyses included the quantified values of attributes of service quality, including frequency and reliability. By using the updated values in the cost model developed by Morales-Fusco et al. (2012), Galati et al. (2016) compared different transportation scenarios (i.e. road-only transport, road transport with Accompanied-SSS, and road transport with Unaccompanied-SSS) for olive oil distribution from Spain to Italy and found that road-only transport was the most expensive option.

Focusing on the East Adriatic and Ionian Sea region, Tsamboulas et al. (2015b) identified prospective intermodal SSS links that are financially competitive under the European Commission's MoS programme. Martell et al. (2013) conducted a comparative cost analysis of road and SSS services in 112 Western European cities, the results of which suggested that SSS services perform better in terms of cost but rarely in terms of time. Thus, they highlighted the need for speed on the maritime legs of SSS chains.

A few articles have demonstrated that including external costs can affect the cost-competitiveness of SSS. Chang et al. (2010) and Suárez-Alemán et al. (2015a) estimated and compared the total costs of transport and time, including the external costs of air pollutants and greenhouse gases for road, rail, barge, and SSS in South Korea and Europe. Sambracos and Maniati (2012), Perez-Mesaa et al. (2012) and Juste and Ghiara (2015) performed similar comparisons for road haulage and SSS services in the Mediterranean region. A distinct feature of their studies was that to evaluate external costs, they include not only air pollution but also the other externalities such as highway congestion, noise emissions, climate change (global warming impacts), nature and landscape

damages, and traffic accidents. By comparison, Lee et al. (2010), López-Navarro (2014), and Kotowska (2016) did not take into account generalised costs in their analyses but evaluated and compared only the external costs for road haulage and SSS services in Taiwan and Europe. Overall, the cited articles have indicated that including external costs in cost comparisons can make SSS seem more competitive.

Service quality performance. A number of articles have assessed the importance of service quality attributes that are considered by the shippers and play an important role in mode choice decisions. In this respect, D'Este and Meyrick (1992), D'Este (1992), Bergantino and Bolis (2008), Brooks and Trifts (2008), Puckett et al. (2011) and Brooks et al. (2012) compared the importance of service quality performance between road haulage and SSS from Australian, Canadian, Italian, and US forwarders' and shippers' perspectives. Their findings revealed that, among other factors, certain attributes of service quality, especially shorter transit time, frequency of a service, and reliability are more important than the higher freight rate paid for cargo transport. In support of these findings argues that the indirect and long- term costs of failure to deliver consignments on-time and intact may result in loss of markets and market share, loss of customer confidence and opportunities forgone.

Environmental performance. The better environmental performance of intermodal SSS versus road transport is often presented as an argument by policymakers to encourage the modal shift to SSS. In that regard, Hjelle (2010), Hjelle (2011), Corbett et al. (2012) and Hjelle (2014) evaluated the environmental performance with respect to for example CO_2, NOx, and SOx emissions from road haulage versus SSS options in Europe and the United States. They found that due to factors such as high fuel consumption and lower load factor, intermodal SSS generates more emissions, at least in the scenarios analysed, per tonne-kilometre than road haulage. Nealer et al. (2012) and Rodrigues et al. (2015) compared the CO_2 emissions produced by alternative modes using different scenarios for the United Kingdom and the United States. Both groups of authors proposed that measures such as using cleaner fuels in road haulage and improving the truck emissions-efficiency via innovative technologies might be better strategies to minimise CO_2 emissions in the transport sector than using SSS.

Research gaps. The use of different methods in different trade corridors and the inclusion of dissimilar factors in analyses of competition has generated inconsistencies in the results presented in the reviewed articles. For example, some have considered only the operating or fixed cost of a transport mode while overlooking the financial value of attributes of service quality or external costs. Similarly, most research on the fuel consumption and emissions of vessels is based on the assumptions or information provided by stakeholders, which may have prompted over- or underestimation of the results. Therefore, we emphasise the need for more route-specific research that is based on realistic data concerning the usage rates of vessels and trucks and their respective fuel consumption, as well as that incorporates all three dimensions of performance in its analyses. Such efforts would also call for research with measurements taken aboard ships of external effects and the development of detailed cost models.

In addition, technological innovations have revolutionised the freight transport industry, in which self-driving electric trucks and self-navigated electric SSS vessels might become realities. Such automation can substantially alter the cost and profitability structure of a transport mode as well as significantly reduce its environmental impact.

Accordingly, that possibility needs to be assessed in future research by, for example, evaluating the automation of ships and the use of alternative fuels.

3.2.5. Port characteristics (C5)

As central nodes for SSS activities, ports could play an instrumental role in enhancing the efficiency of SSS systems, which is essential for SSS to compete with road haulage, by reducing overall lead times and associated logistics costs. In six articles, scholars have addressed the impact of port characteristics and policies concerning SSS competitiveness and the modal shift from road haulage. Among them, Paixao and Marlow (2007) and Tsamboulas et al. (2010) emphasised that the development of major port-oriented attributes – port harmonisation, use of electronic data identification systems, port – hinterland connectivity, and administrative and customs procedures – are crucial to ensuring a modal shift to integrated SSS. In the same vein, Baindur and Viegas (2012) asserted that policy measures such as port liberalisation and improved port–hinterland connectivity can reduce the total cost of SSS services and facilitate faster cargo movements. In other work, Suárez-Alemán et al. (2015b) and Ng (2009) compared the monetary cost (i.e. price) and time cost of alternative transport modes and claimed that enhanced port efficiency strengthens the competitiveness of SSS.

Suárez-Alemán and Hernandez (2014) have suggested that promoting port efficiency might be a more suitable target than subsidising shippers to use SSS. Viewing port efficiency as time spent at a port, they investigated the potential effects of offering a subsidy per unit of reduced inefficiency to show that instead of providing fixed amounts to ports, a proportional payment that hinges the subsidy on improved port efficiency could be a better mechanism for incentivising ports. An improved port performance can eventually enhance the performance of SSS by reducing the total lead time.

Research gaps. Port efficiency and performance constitute an extensively studied area in scientific work on deep-sea ports. However, performance and efficiency from the perspective of SSS in ports should be other important topics in future research. Detailed data collection at port authorities regarding the volumes, costs, employees, and number and type of companies in SSS needs to be conducted for performance analyses.

At the same time, disruptions in ports can prompt disruptions in supply chains, which can deter transport buyers from choosing SSS. That dynamic is particularly important given that reliability and a poor image of SSS have been identified as two important barriers to its use, especially when European ports have had to cope with blockades and labour strikes. Such strikes at ports severely disrupt shippers' supply chains by crippling port operations and, in turn, can make SSS unattractive. Furthermore, in today's era of digitalisation, information technology (IT) systems are prone to cyberattack. For instance, on 27 June 2017, one of the world's largest container terminal operators, APM, suffered a cyberattack that halted its 76 terminals around the globe. Consequently, loading and unloading times at its terminals rose considerably, and customers received their cargo a few days later than expected. Thus, those types of disruptions can dissuade cargo owners from relying entirely on SSS. In response, we believe that research on supply chain disruptions and risks is important, especially if it can include investigations of the capacity of current IT systems as well as their safety and security risks.

3.2.6. The multi-agent perspective (C6)

The success of SSS depends on the seamless integration of individual services offered by agents, or actors, across transportation chains, as addressed in four articles. Saldanha and Gray (2002) emphasised that integration requires the cooperation of all agents within a multimodal logistics chain. They found that though both road haulage and SSS firms favour cooperation, the highly competitive and go-it-alone strategies of SSS firms prevent such cooperation. Similarly, Paixao and Marlow (2005) have suggested that to facilitate their integration into intermodal transportation chains, SSS firms should offer forwarding services and form partnerships with other agents in their chains. Such partnerships could strengthen the competitiveness of intermodal SSS versus unimodal road haulage.

Paixao and Marlow (2009) underscored best practices and strategies for logistics integration, including total quality management, freight-forwarding, partnerships, customs clearance, and outsourcing, all of which can improve customer service by enhancing the tracking and tracing of cargo and transport modes along transportation chains. Later, with a sample of 106 relationships between SSS and road haulage firms, López-Navarro (2013) verified that shared planning and joint decision making in the transportation chain positively affect the performance of both types of firms. Such cooperation can help firms to find mutually satisfactory solutions and improve the integration of both agents in intermodal transport chains.

Research gaps. Although shared planning, coordination, and alliance among members of transportation chains are essential to ensure the integration of SSS into intermodal transportation chains, research on inter-organisational relationships in the context of logistics chains involving SSS has been rare, at least as represented in the literature reviewed. Synergies among agents in transportation chains can offer better visibility, reduce costs, and enhance the responsiveness of intermodal transport chains, all to meet shippers' demands in more flexible, timely ways. We believe that more research that evaluates the economic or financial benefits of coordination for each agent in a logistics chain is needed, for the results of such work might encourage them to recognise the importance of integration within supply chains. The emergence of new technological solutions such as the internet of things and blockchains have the potential to overcome factors hindering the modal shift to SSS by enhancing trust, reliability, and collaboration among transportation chain agents and by increasing the efficiency of supply chain activities. Researchers should also focus on specific trade corridors and cases in which coordinated and shared IT system capabilities (e.g. via blockchains or the internet of things) have improved efficiency and reliability as well as lowered costs. Studies on the design of IT systems and expected savings in terms of costs and efficiency, along with increased reliability, are also needed, for their results could enhance the competitiveness of SSS.

4. Conclusion and research directions

As evinced by the increasing number of published articles on the topic, which has been more observable since 2011 (Figure. 2), the modal shift from road haulage to SSS has become an important topic of research. This paper has provided an overview of recent studies on the topic and identifies paths for future research.

A summary of the chief features of the literature reviewed (i.e. 58 articles on the modal shift) has been provided as the result of a descriptive analysis. The findings of the analysis highlight that the majority of the articles (i.e. 45 of 58) have focused on EU countries, possibly because several such countries are connected well by waterways and because the European Union has enacted various policies to promote modal shift as a means to mitigate the rise of road-related negative externalities. With respect to methodology, literature reviews and mixed methods (i.e. qualitative and quantitative methods) have dominated in research addressing the modal shift. Nevertheless, the authors of a few articles deployed surveys, mathematical models, interviews, and case studies in their work.

As a result of content analysis, the reviewed research was classified according to topics in six categories. For a modal shift to take place, SSS as an alternative to road haulage needs to have superior performance (C4). However, since the modal shift is not satisfactory so far, researchers have investigated factors influencing the competitiveness, i.e. barriers and drivers towards a modal shift (C4), as well as how policy measures can facilitate the modal shift (C2). These are the core issues of the modal shift and by far the most researched categories so far. For the modal shift to progress further, we believe that these are the most pressing issues to understand even better. From the review, the following venues for further research are provided;

First, to evaluate the competitive performance of SSS in different trade corridors, data should be gathered about three primary dimensions of performance: the economic dimension, the environmental dimension, and the dimension of service quality. Route-specific performance analysis incorporating real-world data about capacity usage and fuel consumption rates as well as all three performance dimensions should help policy-makers to identify the most competitive transport mode for certain routes and could trigger SSS-oriented policy actions and investments needed to increase SSS performance. SSS firms using the results of such performance analyses might detect areas in which their performance is weak and devise strategies to improve their operations.

Second, rich, real-world, numerical data and operational research techniques are needed to identify the relative importance of individual drivers of and barriers to the satisfactory performance of SSS. Such endeavours would require EU member states to allot considerable amounts of money during a long-term yearly schedule, because collecting data about transport volumes, ship characteristics, costs, emissions, companies, employment, and services is a costly, time-consuming activity. Nevertheless, the collected data could inform policies geared towards affecting the modal shift from road haulage to SSS.

Third, several articles have revealed that policy, both economic and regulatory, is important to support the modal shift from road to sea, although the outcomes of such policy has been dismal. Identified reasons include that policies are somewhat misdirected, meaning that future research should focus on developing proper measures based on the unique characteristics of sea transport. Furthermore, it is important to pinpoint which groups of actors certain policies should target. Researchers should also extend their policy-oriented focus beyond the European Union to assess whether and, if so, then how it is possible to internalise the external costs of transports. Creating a large database of information about past SSS policy projects would facilitate the analysis of factors of policy success and failure.

Researchers have also acknowledged the importance of understanding impact of environmental legislation (C3), port characteristics (C5) and the multi-agent perspective (C6). Though aforementioned venues for further research may be the most important,

we do believe that it is important to continue research on these areas as well, and suggest the following;

Fourth, determining strategies that moderate the adverse impacts of the recent sulphur regulations and other legislation on SSS is suggested. In that respect, providing subsidies to SSS on affected routes or imposing taxes on rival unimodal road haulage might be relevant strategies. However, such work entails not only computing the size of subsidies needed to be provided to SSS services operating in certain trade corridors and the taxes to be implemented on road haulage but also evaluating the potential benefits of such subsidy and tax policy. Policy actions based on these proposed strategies could reduce the negative impacts of regulations on SSS. In addition, measurements aboard ships should be taken to gather real-world data about emissions.

Fifth, the influence of contingencies, particularly port strikes and cyberattacks, on SSS operations and approaches for navigating such contingencies should be investigated. Contingencies in SSS disrupt shippers' supply chains and can persuade shippers to use alternative transport modes as part of their strategies to mitigate risks, which can reduce business volumes for SSS.

Sixth and last, the economic or financial advantages of coordination and alliance for each transport chain agent need to be evaluated. The results of such evaluations might encourage transport chain agents to realise the importance of integration within the supply chain, which could enhance the competitiveness of intermodal SSS.

Altogether, research responding to those suggestions can contribute to creating new insights into SSS usage.

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