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A survey of short sea shipping and its prospects in the USA

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The continuing growth of international container trade has created capacity problems at major US ports, and the truck-based freight transportation has caused a deterioration of traffic congestion on important US transportation corridors. Using inland and coastal waterways, short sea shipping (SSS) can provide an improvement to these problems. Furthermore, SSS offers many additional benefits for the environment, the economy and society as a whole. Both the US Department of Transportation and the European Commission actively support SSS as an alternative, environmentally friendly mode of transportation. However, there are obstacles, administrative barriers and challenges that should be addressed. Several successful operations on both sides of the Atlantic make a strong case in favour of SSS. SSS can develop customized and technologically advanced solutions that will further integrate it into the intermodal transportation chain and will improve its image among shippers as a mode that can provide reliable door-to-door transportation. This paper reviews several studies on the subject and discusses the latest developments on SSS in the US and in Europe. It also addresses the major issues and the benefits of SSS and examines the prospects for potential short sea operations in the US. Finally, it proposes research opportunities for a multimodal transportation system that will include a short sea component.

1. Introduction

US international trade, especially imports of containerized cargo, is growing steadily with an average growth rate of 7% since 1980. Container traffic through the US ports reached 45 million TEUs in 2007 (figure 1). The US Department of Transportation (DOT) forecasts that by 2020, even at moderate rates of domestic growth, the international container trade will double from its current levels [1]. This cargo flow surge has placed significant stress on the US transportation network. The major coastal ports are currently operating near their maximum capacity, suffering from 'bottlenecks' and delays in container movements. According to the American Association of Port Authorities (AAPA), the average 'dwell' time of containers sitting idle in the yard is six to seven days for the US ports, compared with only one to two days or even hours in some Asian ports.

Furthermore, the increase of general cargo transportation, which is been carried mostly by trucks, has caused environmental and societal problems, such as traffic congestion, air pollution, highway accidents and increased energy consumption. In 2007, congestion cost an estimate of $78 billion in wasted fuel and lost time [2].

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Truck traffic contributes significantly to congestion on major coastal interstate highways, such as the I-95 and the I-5. Highway or even rail expansions are too costly and require a significant amount of time to accommodate this imminent freight traffic growth. The US Federal Highway Administration (USFHWA) estimates that the average cost of highway construction is $32 million per lane mile, without including the cost of interchanges, bridges, or other environmental costs.

Short sea shipping (SSS) is a sustainable and environmentally friendly solution for the capacity and mobility problems of the US freight transportation system. Although there is no worldwide consensus on the definition of SSS, the definition given from the US Maritime Administration (MARAD), 'as a form of commercial waterborne transportation that does not transit an ocean and utilizes inland and coastal waterways to move commercial freight', is the most widely accepted. The focal point of SSS in the US is the transportation of containerized general cargo. SSS offers many advantages over the land-based transportation modes; it is more energy efficient, more environmentally friendly, safer and requires less public expenditures on infrastructure. It can add more capacity to the transportation network, which is necessary in order to accommodate the future growth of the international trade, at a relatively low cost. Overall, SSS can generate more public and environmental benefits.

The practice of using the waterways for transporting cargo is known since the ancient times, when commodities were traded with ships travelling within sight from the coasts. In the US, commodities were transported along the navigable rivers of Mississippi, Ohio and in the Great Lakes. However, the rapid growth of road and rail transportation in the twentieth century led to the decline of coastal and inland shipping. Currently, only about 9% of the total cargo in weight, mostly bulk commodities, is been transported by water in the Mississippi river system and in the Great Lakes, compared with more than 60% that is been transported by trucks [3]. The recent deterioration of traffic conditions in the land transportation networks has renewed the interest for SSS. Both MARAD and the European Commission (EC) are trying to revive it as a new alternative and sustainable mode of freight transportation.

In Europe, the EC actively supports SSS through funding of short sea projects, since 1992, under its common transport policy. SSS has become a fundamental cornerstone of EU's transport policy, a major component of the Marco Polo

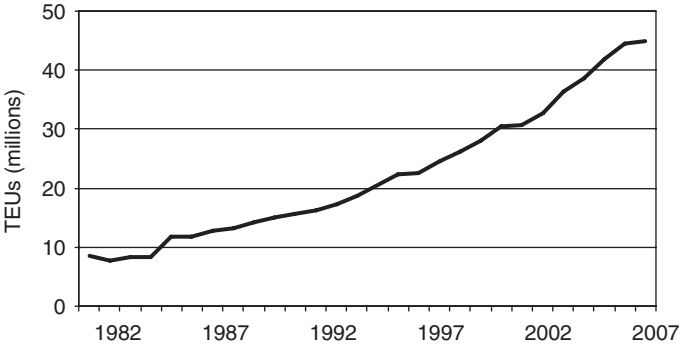

Figure 1. Container traffic at US ports.
Source: American Association of Port Authorities, 2008.

programmes and a part of the Trans-European Networks (TEN-T). In 2001, the *White Paper on European Transport Policy for 2010* emphasizes the significant role that SSS can play in curbing the growth of truck traffic, rebalancing the modal split and bypassing land bottlenecks [4]. In the US, MARAD leads the way in promoting the idea of SSS with its Marine Highway Initiative. In December 2007, the US Senate passed the latest Energy Law (HR 6), which has with a section dedicated to the promotion of SSS as a sustainable mode that can alleviate highway congestion [5].

The paper starts with a description of the two main types of SSS and with examples of such short sea operations. Then, it reviews several studies and reports that were conducted in Europe and in the US. Subsequently, it states the benefits of SSS and the barriers to its expansion in a strength-weaknesses-threats-opportunities (SWOT) analysis framework. Finally, it gives some recommendations on how scientific research can be applied for the successful integration of SSS into the intermodal transportation chain.

2. Two types of short sea shipping

There is no strict taxonomy of SSS. SSS can be categorized according to the type of transported cargo, the types of vessels or the waterways that are been used. In the US, there are two major types of cargo units for the transportation of general cargo; the freight containers, conforming to the International Standards Organization (ISO) standards of construction and dimensions, and the truck-trailers or semi-trailers. The ISO containers appear primarily in two standardized sizes: 20 feet long or twenty-foot equivalent units (TEU) and 40 feet long or forty-foot equivalent units (FEU). They represent the majority of international general cargo traffic at the US ports. Trailers, mostly 53-feet long, are the dominant truck-mode cargo units on highways, used for the transportation of domestic cargo, i.e. cargo that originates from a US source. SSS can provide transportation options for both of these types of cargo. Small containerships, i.e. feeders, with lift-on lift-off (lo-lo) capability or container barges are suited for container transportation on coastal or inland waterways. Respectively, vessels that can transport truck trailers and other form of wheeled cargo are the roll-on roll-off (ro-ro) ships. Table 1 presents a list of existing

Table 1. Existing short sea operations in the US.

Company name	Vessel type	Geographical area
Alaska Marine Lines	Container barges	Washington state—Alaska
Bridgeport Feeder Service	Ro-Ro ships, container barges	New York—Connecticut
Columbia Coastal Transport	Container barges	US east coast—Bahamas
Crowley Maritime	Lo-lo, ro-ro ships	US east coast—Caribbean, Mexico
Foss & Tidewater Barge Lines	Container barges	Columbia/Snake river
Horizon Lines	Lo-lo ships	WA-AK, CA-HI, US east coast–PuertoRico
Osprey	Container barges	Gulf Coast, Mississippi river
Totem Ocean Trailer Express	Ro-ro ships	Washington state—Alaska

Source: SNAME Panel O-36, 2002.

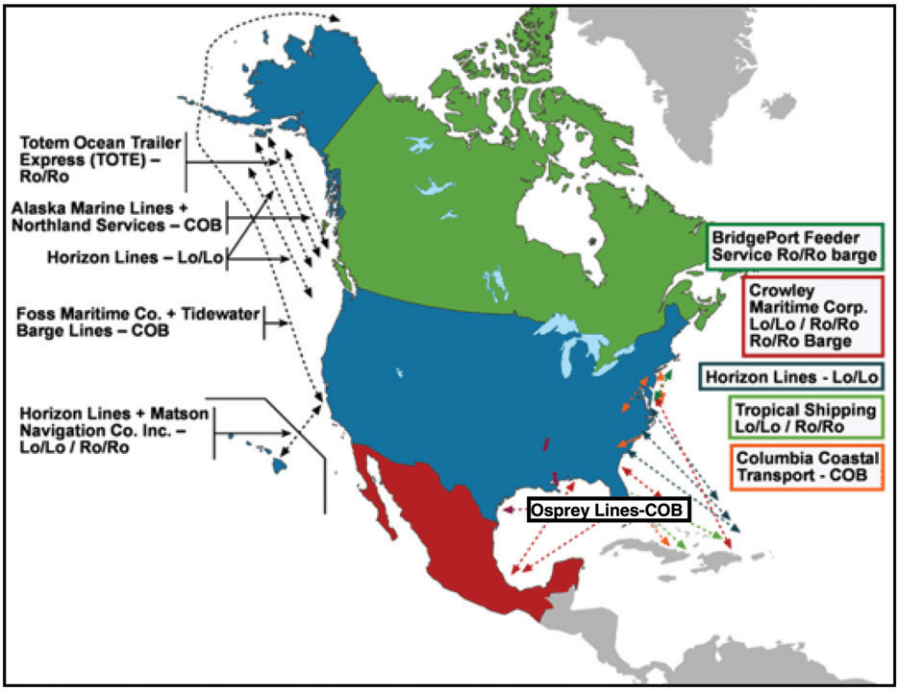

Figure 2. Short sea operations in the US.
Source: MARAD, 2006.

short sea services in the US and the geographical area where they operate, which is also is depicted in figure 2. Most of them, however, operate in non-contiguous trade lanes, where they have captured captive markets due to limited competition.

The following two general applications of short sea services are not an exclusive classification of SSS. These applications can provide realistic solutions for two major freight transportation problems, that of port capacity and of highway congestion. Successful examples of these waterborne freight transportation services can serve as models for future SSS operations.

2.1. *Feedering international containers with lift-on lift-off feeder vessels or container barges*

The rapid growth of the international container trade has created capacity problems and inefficiencies at the major US container ports. The terminal productivity of the US ports, in terms of annual container throughput per acre, is approximately three times lower than the productivity of the major Asian ports. Additionally, there are high delays for the trucks, which have difficulties reaching the port terminals due to traffic congestion and port inefficiencies. The upcoming arrival of the new post-Panamax mega-containerships will further deteriorate the situation. A solution to the terminals' efficiency problem is to use smaller feeder ports or satellite terminals and tranship directly the containers there for distribution to their final destination. In other words, create a short sea hub-and-spoke system, where the major hub ports receive the international containers and tranship them immediately to smaller ports using a fleet of smaller containerships or container barges. This is a form of SSS also

known as 'feedering'. The cargo that can be transported this way is mostly international containers.

On the east coast, the Port Authority of New York and New Jersey (PANYNJ), facing port space limitations and an influx of international cargo, established the Port Inland Distribution Network (PIDN). PIDN is a public–private partnership that carries containers from the Ports of New York and New Jersey for distribution to an inland distribution network of satellite feeder ports, such as the ports of Bridgeport in Connecticut, Camden in New Jersey, Providence in Rhode Island, Albany in New York and Boston in Massachusetts using container barges and trains [6]. PANYNJ estimates that by 2020 container barges will transport almost 20% of the port's container traffic. In addition to relieving road congestion, the PIDN will lower the inland distribution costs and it will expand the port's throughput capacity. It will also reduce the truck trips (vehicle miles travelled), it will improve air quality, it will save energy through reduced truck fuel use and it will overall benefit the environment. The feeder ports can experience economic development by providing new port infrastructure for value-added warehousing and distribution opportunities. However, there are still significant financial and infrastructure challenges for the development of the PIDN. Another example of container distribution is Columbia Coastal Transport, LLC, which operates a fleet of ten container barges in five sea routes linking major ports in the US east coast and in the Caribbean. Columbia Coastal is a part of a larger transportation company that offers complete freight transportation services, including truck transportation to the final destination. Annually, it moves approximately 100 000 containers on the US east coast. Similarly, Osprey Lines LLC operates container barges and offers transportation services in the US Gulf Coast and in the Mississippi river system. Container barges connect Houston, Lake Charles, New Orleans, Memphis, Chicago, Mobile, Pascagoula and other US Gulf Coast and inland river ports. Several ports, such as the port of Canaveral in Florida and the port of Bridgeport in Connecticut, have already conducted their own feasibility studies in order to position their ports as future feeder ports or distribution centres, which will receive containers from the major hub ports of New York and Hampton Roads.

2.2. *Transportation of domestic trailers with roll-on roll-off ships*

The increasing number of trucks on the major highways has created environmental and societal problems, such as road congestion, air pollution, road accidents, etc. SSS offers an alternative method for the transportation of domestic cargo, mainly semi-trailers, using the waterways. Short sea operations can create an intermodal transportation network that will modally shift cargo from the highways to the sea for medium and long-haul distances. Ro-ro ships can provide an economical and reliable way for truck-trailer transportation in geographical areas such as the US east and west coast, the Gulf of Mexico and the Great Lakes. For long distances, SSS can be very competitive due to economies of scale and its fuel efficiencies. Trucks will do the short-haul pick up and the delivery of the cargo to its final destination, i.e. 'drayage'.

Examples of such short sea services, in the US, are the Totem Ocean Trailer Express Inc. (TOTE) and Crowley Maritime Corporation. TOTE operates a fleet of ro-ro cargo ships from the US west coast to Alaska, between the Ports of Anchorage and Tacoma, Washington. Additionally, TOTE provides overland highway and intermodal connections throughout greater Alaska, the lower 48 states, and Canada. Crowley operates ocean cargo carrier services between the US and the Caribbean.

Its services include regularly scheduled liner operations for cargo shipped in containers or trailers. Several other successful short sea services operate in the non-contiguous US domestic trade lanes, such as between the continental United States and Puerto Rico, Alaska and Hawaii, which are considered as captive markets with limited competition. It is also noticeable that these successful short sea operations provide complete door-to-door, intermodal transportation services. Therefore, they can offer a business model that can be applied to future short sea ventures in coastal routes.

The Commonwealth of Massachusetts is investigating SSS options for its small- and medium-sized ports, in order to initiate short sea services along the US east coast and Canada. They focus mainly on domestic transportation of 53-feet trailers using ro-ro ships. A proposed short sea service will connect the ports of Fall River and New Bedford, Massachusetts with other major US east coast ports and will provide a modal shift for freight that is currently moving over the I-95 highway [7]. In Europe, one of the most successful short sea operators is Samskip with a comprehensive transport network, which spans all of western Europe. Samskip offers frequent services between the European continent and various destinations in the UK, Ireland, Spain, Portugal, Scandinavian countries, Poland, the Baltic States and Russia. Furthermore, it is an intermodal provider that offers fast and reliable service by choosing the optimal geographical and economical routing. Its extensive fleet of containers can move via ship, road, rail or barge.

There is a lot of discussion about what will be the most successful trend for SSS; ro-ro ships carrying domestic 53-feet trailers or feeder ships and container barges carrying international containers? The majority of truck traffic on congested highways along the two US coasts, such as the I-95 and I-5, is from truck-trailers. Advocates of SSS propose a system that will use ro-ro ships, which will perform a ferry-type service and therefore will result in removing trucks from the coastal highways. The trucking industry can be a partner for such SSS operations [8]. Many truckers have already become supporters of SSS and they view it as a bridge to new businesses rather than a direct competitor. Therefore, alliances or even direct investments from the trucking industry can be expected in the near future. On the other hand, the 'bottlenecks' at the container ports that were caused from the surge of international trade appear in the form of ISO containers. Consequently, port authorities have expressed their interest for short sea feedering services. The PIDN from the port of New York is such a typical concept. Based on the presented two types of SSS, table 2 summarizes the main characteristics and the differences between a ro-ro trailer service and a lo-lo container transportation.

3. The European experience

Since 1992, the European Commission (EC) supports SSS under its common transportation policy initiatives. Three roundtable conferences dedicated on short sea shipping were organized from 1992 to 1996. These conferences identified the main policies and the role of the EU in the development of SSS [9, 10]. In 1995, the Short Sea Shipping Concerted Action was established with the goal of compiling and synthesizing any published research done in the field of SSS [11]. This effort, although it provided a framework for discussion on the major issues and promoted the idea of SSS, also revealed the difficulties of applying SSS in the transportation reality. The main proposed strategy was the integration of SSS into Europe's

Table 2. Comparison of the two types of short sea operations.

Vessels	Ro-Rro ships	Lo-lo ships or container barges
Cargo carrying units:	Trailers (53')	ISO Containers (TEU or FEU)
Carrying capacity:	200-500 trailers	500–1200 TEU
Cargo origin:	Domestic	International
Time sensitivity:	High	Low
Load & unload time:	Low	High
Port turnaround time:	Low	High
Infrastructure costs:	Low	High
Cargo handling costs:	Low	High
Projected required freight rate ($/unit):	High	Low
Potential alliances with:	Trucking industry	Ports

intermodal transportation networks. The recommended steps were further co-operation among various transportation modes, alliances among ports, i.e. 'port pairing', and the development of a common system for freight transportation data. Rail and short sea projects have been financially supported since 1992, under the Pilot Actions for Combined Transport (PACT), a programme that was designed to foster innovative actions that can improve the competitiveness of combined transport. From 1992 to 2000, the PACT programme has financed a total of 167 intermodal projects, with 92 of them been funded after 1997. Several short sea operations, mostly in northwestern Europe, using container barges on inland waterways are considered even today as successful models for future SSS applications.

Regardless of these efforts, from 1990 to 1999, SSS increased at a slower rate, 30%, than the road freight transport, which increased by 41% in terms of ton-kilometres. In 2001, SSS had 40% of the total ton-km, while road transport had a share of 45%. In cargo tons alone, road transport is still the dominant mode of freight transportation with about 80% of total tons of freight. European SSS is deployed mostly in longer routes with an average distance of 1385 km, while trucks have an average distance of 100 km. Rail has a small share of freight transportation in Europe [12, 13]. The lack of sufficient data of the cargo flows, which are necessary to define any modal shift that will create a SSS market, was mentioned as one of the main reasons for the lower than expected results. As another cause, European port authorities are blamed for outdated practices, lack of investments in port infrastructure and for preventing international private operators investing in their port terminal infrastructure.

Despite the lower than expected results, the EC is committed to its support of SSS. A major boost for the promotion of SSS in Europe was the establishment of the Marco Polo programme in 2001, as a successor of the PACT programme, with the broad objective to enhance intermodality. The programme ran from 2003 to 2006, with a total budget of €102 million. Its main actions included the establishment of 16 national promotion centres, the development of more accurate statistical cargo data, the reduction of the paperwork and improvements in port infrastructure. In July 2004, the EC presented the expanded Marco Polo II programme, which includes new initiatives such as the Motorways of the Sea concept in four European regions. The programme, which has a budget of €400 million for the 2007 to 2013 period, has also

been extended to countries bordering the EU [14]. The EC estimates that every €1 in grants will generate at least €6 in social and environmental benefits. The programme has specific targets of cargo volume to be shifted from road to sea mode. Intermodal projects that will contribute to that modal shift will be funded up to 35% from the programme's budget. Five types of actions will be supported:

1. Modal shift actions, which will shift cargo from road to rail or SSS.
2. Catalyst actions, which will promote innovative ways in lifting barriers for intermodal transportation.
3. Motorways of the Sea actions that will achieve door-to-door service.
4. Traffic avoidance actions that will reduce the demand for freight transportation.
5. Common learning actions that will enhance the knowledge in the freight logistics sector.

In another recent display of strong support for SSS, the EC has funded a research project, named CREATE3S, which aims to develop a new generation of standardized short sea vessels. Utilizing advanced design and manufacturing techniques, the proposed vessel is consisted of two modules, one ship hull module and one large cargo module, which allow it to unload its cargo in one move. The project brings together private and public companies and has a budget of €4.2 million.

The EC initiatives have also triggered scientific research on SSS. Paixão and Marlow [15] presented the first analysis of SSS as an alternative mode of transportation. They evaluated the strengths and weaknesses of SSS in Europe. The weaknesses are mostly related to the port environment and the quality of service that SSS can provide. Barriers to its expansion are the lack of efficient port operations, unreliable vessel schedules, excessive paperwork and administrative costs. The advantages of SSS are its environmental benefits, the lower energy consumption, the economies of scale, and the lower costs needed for infrastructure expansion. If certain measures are introduced the disadvantages of SSS can be overcome. This was the first research approach, which defined the major issues. In 2005, the same authors published a second article about SSS [16]. Given the lower than expected results by that time, they examined the competitiveness of SSS in comparison with the other transportation modes, in terms of the level of service that SSS provides to its customers. Based on a questionnaire sent to 332 industry participants, an analysis of the current short sea market environment is performed. The analysis revealed the low quality of service that SSS provides, but also its poor image compared to the other transportation modes. The short sea shipowners should change their corporate attitude and integrate their businesses to the modern just-in-time logistics as a way to improving the image of SSS. The study uses marketing tools in order to determine the performance of SSS on customer service satisfaction.

A different approach on the competitiveness of SSS is presented by Musso and Marchese [17]. They provided an overview of SSS, its different markets and they examined its advantages and disadvantages. They also proposed an economic framework, based on the 'à la Hoover' approach, for the economic and geographical conditions that can make SSS competitive. These conditions define the critical thresholds for the optimal trip distances and the corresponding costs, under which SSS is more competitive than the other land modes. Although, it appears as a simple methodology, the interaction of transportation costs with trip

distances is interesting. SSS competitiveness depends directly on the sea-leg distances. Under the term cost the authors mention that all the costs, both internal and external costs, such as environmental and social costs, should be included.

There are several successful and innovative examples of SSS in northern Europe. At the Port of Rotterdam, about 25% of the container traffic is been carried by container barges on inland waterways. This operation was materialized with the application of modern logistics and integrated business practices among shippers and port operators. The success of container barges in rivers has shown that vessel speed may not be the most important factor for SSS success. On the contrary, investments in vessel capacity and cargo handling equipment may yield better returns and better level of service than investments in ship propulsion [18]. The Baltic region has also experienced a significant growth of SSS, where it offered shippers an alternative to deteriorating road conditions and an easy access to Russia's markets. Shipping companies providing short sea operations in the region saw their profits grow substantially in 2006.

There are, however, some distinct differences between the European and the US freight transportation networks, beyond the given geographical differences. For example, rail mode in Europe is perceived mostly as a passenger transportation mode, while in the US cargo trains have about 30% market share of the freight transportation in ton-miles. Roads in Europe are considered to be more congested and in some areas, such as in the Alps and the Pyrenees, road expansion is extremely difficult. The main motivation behind the SSS promotion and expansion is its environmental advantages over the other modes of freight transportation. EU strongly supports SSS by financing projects that can initiate a modal shift from road to sea mode, because of the high external costs of truck transportation.

4. SSS studies conducted in the US

In the US, the Department of Transportation (DOT) has made SSS a high priority in its National Freight Action Agenda. The first SSS initiative was launched in November 2002. MARAD currently leads the way in promoting the idea of SSS with its Marine Highway initiative. MARAD's vision is using SSS to reduce freight congestion on road and on rail transportation networks by increasing intermodal capacity through the underutilized waterways. MARAD has organized four conferences on SSS from 2002 to 2006. The main purpose was to raise awareness on SSS and further stimulate short sea operations. Stakeholders, from public and private transportation sectors, acknowledged the viability of SSS as an alternative transportation mode, but also pointed out existing obstacles, such as port inefficiencies, lack of communication among shippers and shipowners and legal and administrative constraints. The Short Sea Shipping Co-operative Program (SCOOP) was established in October 2003 aiming to further promote SSS and support the co-operation among the transportation modes. Its members are public and private organizations with the goal to exchange information and ideas towards reducing congestion and improving freight mobility in the US. In November 2003, Canada, Mexico and the US signed a Memorandum of Co-operation on Short Sea Shipping. Under the Memorandum, the three countries will cooperate in sharing knowledge and information on SSS, and support any research or development efforts about SSS [19].

All these promotional efforts have already led to some action. In 2007, the US Congress has passed the following bills that support the idea of SSS. The 'New Direction for Energy Independence, National Security, and Consumer Protection Act' (H.R. 3221) and the 'Transportation Energy Security and Climate Change Mitigation Act of 2007' (H.R. 2701) direct the DOT to establish programmes for short sea transportation and to designate short sea shipping projects in order to mitigate landside congestion on interstate highways [20, 21]. These bills would provide $100 million over four years for the financing of short sea operations. Additionally, loan guarantees, up to $2 billion will be available to maritime operators for their short sea projects. The Capital Construction Fund programme was also extended and is now offered for the building of short sea vessels as well. Another bill that calls for the repeal of the Harbour Maintenance Tax (HMT) is the 'Great Lakes Short Sea Shipping Enhancement Act of 2007' (H.R. 1499) [22]. This bill aims at eliminating the repetitive HMT tax imposed on containers each time a vessel enters a US port. The latest Energy Law (HR 6) is also a major boost for SSS.

Most of the research that has been conducted so far in the US was in the form of preliminary and empirical studies that examined the major issues and the viability of certain proposed short sea operations. Their methodology relied on surveys of transportation stakeholders, either by interviews or questionnaires, in order to determine the factors for the success of prospective short sea services in a region. Few of these studies included a market research analysis using cargo flows and projected transportation costs.

The Short Sea Shipping Co-operative Program (SCOOP) has funded three studies on SSS so far. The first study, by the US Merchant Marine Academy, presented an economic analysis of a proposed short sea service with a ro-ro vessel designed to carry 80 tractor-trailers [23]. The estimation of the required freight rate revealed that this is lower than the truck's freight rate for distances longer than 200 miles. This analysis however, did not include the terminal costs and the port fees, which in the case of SSS can be a major part of the total transportation cost. The study also presents a survey/questionnaire that was sent to various industry stakeholders, such as port authorities, shippers, and ship-owners. The results showed that the market size and transportation demand for short sea services are the most critical factors for them.

A comprehensive analysis of the external benefits of SSS is presented in the second study that was conducted by the National Ports and Waterways Institute at the University of New Orleans [24]. These public benefits, such as relieving highway congestion, improving air quality and road safety, are identified and quantified for two cases of prospective short sea operations in the US east coast; a short route from New York to Boston and a longer route from New York to Miami. In both cases, the use of ro-ro ships appears to be very competitive compared with the truck mode in terms of the projected required freight rate, because of the high external costs of the trucks. In the third study by the same institute, these quantified external benefits are applied for the assessment of the Harbour Maintenance Tax (HMT), which is one of the obstacles to the expansion of SSS [25]. The HMT is a fee paid every time a vessel enters a US port for any delivery of domestic or international cargo. The study examined the consequences of a possible elimination of the HMT. The conclusion is that the external monetary benefits of SSS outweigh the revenues from that fee.

Local and state authorities have also taken their own initiatives in promoting the idea of SSS. On the US east coast, the I-95 Corridor Coalition is an alliance of

transportation agencies, 12 US east coast state departments of transportation, port authorities, private, and public organizations. Their main motivation is the alleviation of highway congestion and the negative environmental impact that the trade growth has caused in the region. The Coalition has developed several transportation projects with state and federal funding. A study, conducted by Cambridge Systematics Inc. for the coalition [26], investigated the current situation and the future opportunities for a modal shift from road mode to sea mode on the US east coast. The study is based on existing SSS services and extrapolates their results for future operations. The most important contribution of the study however, is that it tries to estimate the commodity flows and thus to identify any potential short sea market in the region. The authors used the Freight Analysis Framework, developed by the US FHWA, to quantify the commodity flows and highlight the trade corridors. The study did not include a cost-benefit analysis of the external and the total costs of such a modal shift. The authors also conducted a survey with interviews of transportation stakeholders in order to assess their interest on SSS. Overall, their findings show a positive attitude towards prospective short sea operations on the east coast. On the west coast, Westar Transport, a trucking firm, investigated the possibility of establishing a short sea service on the US west coast. They proposed a National Water Highway System with six ships that can carry 20% of the region's general cargo volume. Their published white paper [27] is a description of the proposed operation, which consists of three short sea routes; a north to south ro-ro ship service, a southern and a northern barge service. All the services include commercial and military cargo. The paper gives no further information about the costs of these services.

Another study examined the potential of SSS on the Atlantic Coast of Canada and the north-eastern US [28]. The authors investigated the demand for short sea services and the forecasted cargo flows in the region. They also surveyed a group of shippers in order to determine the critical service requirements that SSS must fulfil. According to their survey, SSS should provide door-to-door services at a competitive price. There is also a strong need for policy changes from the governments of Canada and of the US, in order to make SSS more attractive to shippers. The study revealed marginal opportunities for new SSS services in the region. The case of SSS in Canada is examined, by the same authors, in their 2004 paper as well [29]. The paper describes in detail the regulatory limitations on SSS in North America, from both Canada and the US, which impede the growth of SSS. It also stresses the fundamental issues to be addressed, such as the role of governments in supporting potential short sea operations.

Several port authorities have also conducted their own feasibility studies in order to test how suitable their ports are for future short sea businesses. The Port of Pittsburgh and the Port of Canaveral are two of them. In July 2003, the Port of Pittsburgh Commission completed an ambitious pre-feasibility study for a container-on-barge service that links river terminals from Pennsylvania to Brownsville, Texas and then to Monterey, Mexico. The University of Rhode Island conducted a study for converting a closed US Navy facility at Quonset, Rhode Island into a new container port. The Canaveral Port Authority performed a study in order to determine the possibility of success of future SSS operations [30]. This study includes a decision tool that sets weights on the various decision factors, which determine the possibility of a SSS in the Port of Canaveral. The decision factors are level-of-service indicators that can facilitate or hinder the establishment of a new short sea service.

These weights were determined from previous studies and from one-on-one interviews with SSS stakeholders, i.e. decision makers. Based on the above methodology, a score was estimated, which indicates the probability of success for a new service in the region. The results showed that the Port of Canaveral is in a favourable position for the development of SSS services in the near future.

One of the few published reports, which criticized the direct public funding of short sea services, is the study from the US Government Accountability Office (GAO) [31]. The GAO has conducted an independent review of SSS and its role in the US transportation system. Their area of interest is mainly the financing of SSS. GAO shows an unfavourable attitude towards the generous public funding of SSS and recommends a more systematic evaluation of public investments, based on detailed and rigorous cost–benefit analyses. GAO also proposes a variety of funding tools such as loans, loan guarantees, tax expenditures and joint private and public ventures for investing in port infrastructure and short sea ventures. The study raises one of the most important questions for the future of SSS, which is if federal funding is justified for the support of SSS.

In a study, ordered by the US DOT, the feasibility of SSS is examined in four candidate trade corridors: US Gulf to Atlantic Coast, Atlantic Coast, Pacific Coast and Great Lakes [32]. The study assesses the potential costs and benefits from a number of various perspectives, such as transportation cost, travel times and on-time reliability, capital investments, environmental impact, job creation and security issues. Transportation stakeholders were interviewed and they all, including the truckers, openly stated their interest for SSS. All corridors, except the Pacific corridor, appear to have great potential for viable short sea services. There is enough cargo density to support modal shift from truck mode to SSS, although the domestic coastal market is highly unbalanced, with northbound flows significantly higher than the southbound flows. SSS should provide reliable 'best-in-class', door-to-door transportation services in a competitive price. The study also recommends that the major US container hub-ports should be avoided for new short sea services, in favour of smaller uncongested ports.

5. Benefits of short sea shipping

5.1. *Freight transportation related externalities*

Freight transportation is a major component of international trade. Freight transportation systems transport cargoes from their origins to their destinations, distributing natural resources and other commodities. Therefore, efficient transportation networks are key elements for economic growth. However, the rapid expansion of trucking as the dominant mode of domestic freight transportation in the US (table 3) [33] has caused environmental and societal problems, such as air pollutions traffic congestion, accidents, noise, road damage, etc. These significant side effects are called negative externalities or external costs and are hidden costs imposed on the economy and the society.

Reduction of the transportation-related externalities can be achieved by the implementation of new technologies and by the establishment of new public policies. It can also be achieved operationally by changing transportation patterns and/or switching from road transportation to greener modes, such as the water mode (SSS), thus creating a modal shift. SSS is a sustainable mode of freight transportation that has environmental and societal advantages over the other modes.

Table 3. Modal split of domestic freight transportation.

Commercial freight activity in the United States by transportation mode, 2002				
	Truck	Rail	Water	Other
Tons	60.1%	10.2%	8.6%	21.1%
Ton-miles	34.4%	31.1%	11%	23.5%

Source: US Department of Transportation, Bureau of Transportation Statistics, 2008.

Table 4. Energy use in freight transportation.

Mode of transport	Energy use in MJ/ton-km
Road transport	1.8–4.5
Rail	0.4–1
Maritime/SSS	0.1–0.4
Inland navigation	0.42–0.56

Source: UN Commission of Sustainable Development, 2001.

The main benefits of SSS are the following:

1. *Improved energy efficiency*. The transportation sector utilizes about 30% of all the energy used in the US and freight transportation consumes about 43% of that. Ships are the most energy efficient transportation mode, while trucks are the least efficient (table 4). Economies of scale are in favour of SSS. One 1500-ton barge can carry the equivalent load of 60 trucks or 15 rail cars. Based on the number of miles one ton can be carried per gallon of fuel, an inland barge can travel 514 miles, a train 202 miles, and a truck only 50 miles [34]. This can be translated to significant fuel cost savings.
2. *Reduced air pollution*. Petroleum-based transportation is responsible for air pollution. Residuals emitted as gaseous components and as particulate matter from the internal combustion engines are a major source of air pollution, which has major negative impact on human health and the environment. Common air pollutants are the carbon monoxide (CO), nitrogen oxides (NOx), particulate matter (PM), volatile organic compounds (VOC) and sulphur oxides (SOx). In addition to harmful air pollutants, freight transportation accounts for approximately 9% of the total greenhouse gas emissions in the US, of which 60% is attributed to truck transportation [35, 36]. Sea transportation is the most environmentally friendly mode in terms of fuel emissions per ton-mile of cargo. With the exception of sulphur dioxide, due to the existence of sulphur in marine fuel, SSS is a much cleaner transportation mode than truck and rail in both air pollutants and greenhouse gas emissions, such as carbon dioxide (CO_2) (table 5).

   Environmental research on air pollution cannot precisely measure the negative impact of freight transportation on human health. Even the measurement principles of these effects are being debated. There are wide gaps in the knowledge of the chemical processes in the atmosphere, spatial

Table 5. Emission to air of pollutants in gram per ton-km in function of transport mode.

In gr/ton-km	CO	CO_2	NOx	SO_2	VOC	PM10
Truck	0.25–2.4	127–451	1.85–5.65	0.10–0.43	0.025–1.1	0.04–0.90
Rail	0.02–0.15	41–102	0.20–1.01	0.07–0.18	0.01–0.1	0.01–0.08
Maritime/SSS	0.02–0.2	30–40	0.26–0.58	0.02–0.51	0.04–0.11	0.002–0.04

Source: OECD, 1997.

distribution of emissions, and very limited knowledge on the combined effects of different processes. However, it is clear that increasing the share of sustainable intermodal transportation, such as SSS, is a way of reducing air pollution. The International Maritime Organization has proposed stricter regulation for air pollutant emissions form ships, in order to make shipping more environmentally friendly.

3. *Mitigating highway congestion*. SSS can alleviate traffic congestion by shifting freight from the highways to inland and coastal waterways. Major highways, along the three US coasts (east coast, west coast and the Gulf of Mexico), suffer from congestion. Trucks currently carry about 60% of the domestic general cargo tonnage and contribute significantly to this problem. Trucks delivering their cargo compete with cars for space on highways. This congestion is costly as well. According to the annual urban mobility report from the Texas Transportation Institute [2], traffic congestion continues to worsen in American cities of all sizes, creating a $78 billion annual drain on the US economy in the form of 4.2 billion lost hours and 2.9 billion gallons of wasted fuel for 2007.

   The congestion cost of an additional truck trip is the added delay that it causes to other users of the highway. The added delay occurs because the average speed of the vehicles will begin to decrease progressively once the density of vehicles on the road reaches high volume to capacity ratios. This congestion, which is generally associated with peak-hour traffic, is referred to as recurring congestion. A solution to the highway congestion problem could be a change in transportation patterns from shippers, especially for long-haul trips, with distances greater than 500 miles. Shippers should explore alternative modes of transportation, such as SSS, and consider using SSS instead of truck transportation. Trucks will do the short-haul, pick-up and delivery, at the start and the end of the transportation chain.

4. *Improved road safety*. The US National Traffic Safety Administration estimated that 5282 fatalities occurred in crashes involving large trucks in 1998. The majority, about 75% of people killed in large truck collisions, were occupants of other vehicles or non-motorists [37]. In addition to the high private costs due to loss of life, road accidents cause additional costs to society, such as medical costs, police costs, material damages, which are only partially covered by the existing insurance systems. Furthermore, accidents may also generate additional non-recurrent congestion problems when traffic is dense. Sea transportation is the safest mode in terms of fatalities and injuries.

5. *Reduced highway noise*. Noise is generally perceived by urban residents as an important problem associated with road traffic, both in highways and local streets. In addition to being unpleasant annoyance, noise contributes to health problems. People feel more directly affected by noise than by any other form of pollution. Measuring the magnitude of noise pollution is complex. Volume is measured in acoustically weighted decibels [dB (A)]; a level above 65 dB (A) is considered unacceptable and incompatible with certain land uses in OECD countries. According to the US Environmental Protection Agency (EPA) estimates, trucks are responsible for about two-thirds of the highway vehicle noise emissions. However, noise emissions from highway vehicles are considered not to pose significant human health hazards. There are several characteristics that affect allowable noise levels, such as speed, traffic levels, vehicle weight, and population density. Currently, the EU has established a maximum noise limit of 70dB for urban areas. By removing trucks off the highway, SSS alleviates noise pollution.
6. *Lower infrastructure expenditures*. The capital costs needed for the short sea terminal infrastructure are significantly lower then the infrastructure expenditures for the expansion and maintenance of highways. Currently, the cost for a new highway lane is around $32 million per lane mile and a new interchange on average costs around $100 million according to the US FHWA. Infrastructure costs associated with trucking operations on highways include the wear and tear costs of pavement, reconstruction and rehabilitation of bridges, system enhancement costs, and other miscellaneous items. Costs for pavement reconstruction, rehabilitation and resurfacing are estimated to represent 25% of the total Federal cost obligation. They are allocated to combination trucks on the basis of vehicle miles travelled (VMT) weighted by its passenger car equivalents. The user-fees paid by combination vehicles include Federal taxes on fuels used, excise tax on the sale of heavy trucks, a tax on tires and a heavy vehicle use tax.

The external road damage costs are discussed extensively in Newbery [38]. These costs occur mainly when heavy vehicles cause damage to the road surface, in the form of increased road repair costs and increased vehicle operating costs for the other road users. The damage a vehicle causes to the road pavement increases at the fourth power of the axle road. Therefore, pavement damage is caused almost entirely by heavy trucks. One 80 000 lb tractor-trailer truck does as much damage to road pavement as 9600 cars (US Highway Research Board, NAS, 1962).

5.2. *Quantification of externalities in freight transportation*

The negative side effects of freight transportation can be quantified and monetized as external costs. The sum of the internal (private) costs, those directly borne by the parties involved in the transportation activity, and of the external costs, those borne to parties outside the transportation activity, represents the total social costs of transportation. However, externalities are not taken directly into account by the current price system in freight transportation. There is a discrepancy between the prices for transportation services and the total costs that they impose. If externalities are not considered, markets do not generate efficient resource allocation, so they will not provide the optimal amount of a particular good or service. This is the case with

truck transportation, which has benefited from its low internal costs, aided by the very low fuel prices in the US in the past, and has gained a large modal share.

After identifying the external costs of freight transportation, we must quantify them as marginal -incremental- costs in $/ton-mile or $/TEU-mile. Unfortunately, estimates of external costs are often based on quite different assumptions, making even comparisons difficult. Uncertainties in such estimates are sometimes very large. Externalities are also highly situation-dependent. They vary significantly depending on time and location of the transportation activity, the transportation network and the vehicle type. A number of studies has tried to determine the marginal external costs of transportation, caused mainly by road vehicles. Murphy and Delucchi [39] presented a detailed review of the research that was conducted in the US on the social cost of motor vehicle use. These studies provide estimates of cost functions and data that can help analysts and policy makers evaluate various transportation policies and establish transportation prices. Nash *et al.* [40] examine transportation pricing based on marginal social costs. Such socially optimal, fair and efficient pricing could result in a shift to more environmentally friendly modes and thus have a positive impact on transportation related emissions. The main principle is that the user should bear the marginal social costs, including the environmental costs. Since price, i.e. fare, in transport is a determining factor in modal choice, pricing should be an instrument that will stimulate modal shift to more efficient and greener modes. Small and Kazimi [41] focus on air pollution from motor vehicles in the Los Angeles area. The costs are dominated by the heath effect from particulate matter. Diesel powered trucks are proven to be the most costly. Proost *et al.* [42] analyse the gap between existing and efficient transport prices. Efficient transport prices are those that maximise economic welfare and take into account the external costs, such as congestion, air pollution and accidents].

In the past 20 years, the EC has funded research on the subject of valuation of the environmental damages from energy and transportation with projects such as Externalities of Energy (ExternE), REal COst Reduction of Door-to-door Intermodal Transport (RECORDIT) and Unification of accounts and marginal costs for Transport Efficiency (UNITE). The main methodology used in all of them was the 'impact pathway approach' that was created during the ExternE project. The external costs are estimated by following the pathway from determination of emission, followed by dispersion modelling, then estimation of physical impacts and finally monetary valuation of the impacts. Link [43] summarizes the results of the UNITE project, which compares user payments of tolls, vehicle taxes, and fuel taxes, with the external costs in several European countries. The RECORDIT project focused on the estimation of the private and external costs of intermodal freight transport in Europe.

Governments can use several instruments to internalize and ultimately reduce negative externalities. In general, the three approaches are: regulation, pricing and infrastructure expansion policies. Command-and-control regulation, such as emissions standards, has failed to reduce the expansion of freight truck transportation. Also, the current taxes and fees imposed on drivers do not cover all the external cost of road transportation [44]. A fairer pricing system that will include all the environmental and social costs is required in order the transportation prices to reflect the full costs of transportation activities. Such efficient pricing will be based on the estimation of the marginal social cots of freight transportation for all the available modes and will result in a modal shift to more environmentally friendly modes.

The main principle should be that the user should pay the total marginal social cost of the transportation activity (polluter-pays principle).

5.3. *Additional advantages of SSS*

In addition to the above environmental and societal benefits, SSS has also the following advantages:

1. *Expansion of the transportation network capacity*. SSS can add more capacity to the stressed freight transportation network of the US in an efficient way. Given that the sea lanes or 'marine highways' are in theory limitless, SSS is by far the easiest to expand transportation system.
2. *Port productivity improvement*. By swiftly transhipping containers out of a hub-port, using feeder vessels and container barges, SSS can increase the capacity of the port terminals, reduce the 'dwell time' for containers in the yard and overall improve the productivity of the port.
3. *Revival of the US maritime sector*. The introduction of new waterborne transportation will revitalize the maritime sector in the US. There will be new shipbuilding opportunities for new short sea vessels and therefore employment opportunities as well. The new satellite terminals will also create more jobs for the local communities.
4. *Corporate social responsibility*. The significant environmental and social advantages of SSS over the other transportation modes can lead to different transportation patterns and change the attitudes of the transportation users, i.e. shippers. Under the corporate social responsibility (CSR) concept, businesses make their decisions considering also the interests of other parties, such as the society and the environment, and therefore taking responsibility for the impact of their activities. For example, companies are taking further steps to improve the quality of life for the local communities and the society in general or help the environment. Proponents of CSR argue that corporations gain in the long term in multiple ways by operating with a perspective broader than their own immediate, short-term profits. Several studies have found a positive correlation between social/environmental performance and financial performance [45]. In the increasingly conscience-focused marketplaces of the twenty-first century, the demand for more ethical business processes and actions is increasing and additional pressure is applied on almost every industry to improve its business ethics. Often it takes a crisis to precipitate attention to CSR, such as the crisis in the US freight transportation network. It is also suggested that stronger government intervention and regulation, rather than voluntary action, are needed in order to ensure that companies behave in a socially responsible manner.

The freight transportation industry is a competitive industry. Cost and time are the two main decision-making criteria for the choice of mode. Transportation companies compete on cost and on the level of service been offered, operating under certain standards and regulations. However, the increased awareness on CSR may force them to move further than their compliance with environmental standards. Shippers will start looking at their environmental impact of their transportation activities and may turn their attention to greener modes. SSS has to promote its

image as a sustainable mode of freight transportation and attract environmentally aware shippers. Recent surveys however have showed a lack of awareness about the advantages of SSS among shippers, shipowners, and the public as well [46].

6. Obstacles hindering the implementation of SSS in the US

Despite the wide acceptance of SSS among transportation stakeholders as an environmentally friendly alternative, there are various administrative, legal, operational and financial obstacles that delay the expansion of short sea services. These obstacles are:

1. *Additional handling costs*. SSS adds extra nodes or transhipment points in the transportation chain. Instead of trucks carrying the cargo directly from origin to destination, short sea vessels take over the longer haulage, and trucks make only the local pick-up and final delivery. At the transfer points or intermodal terminals, there are additional handling costs for the loading and unloading of the cargo.
2. *Image problem*. Traditionally, SSS has the image of a slow, unreliable and obsolete mode of transportation. Therefore, shippers are currently reluctant of using this new mode. Several surveys revealed that on-time reliability is the most important priority for shippers. Therefore, SSS should provide a high level of service in terms of on-time reliability, in order me is to alter that image by effectively promoting the advantages of SSS to the shippers and facilitating the c-operation among transportation modes.
3. *Harbour Maintenance Tax (HMT)*. The HMT is assessed as a 0.015% 'ad valorem' fee on the value of the commercial cargo, which is transported on vessels using the US ports. Therefore, it is applied on both domestic and international containers that are been transported by vessels, but not on the cargo that is transported by trucks or rail. This is a major impediment to SSS, since it is applied on every transhipment point. Many transportation industry stakeholders are calling on the waiver of HMT for the domestic SSS transportation. The recent repeal of the HMT in the Great Lakes is a major support for SSS.
4. *Jones Act*. In the US, as elsewhere, one of the major impediments to the development of coastal shipping is the restrictions of 'cabotage' laws. Certain provisions of the Merchant Marine Act of 1920, also known as Jones Act, which requires that any vessel operating between two US ports must be US-built, US-owned, and manned by US citizens, significantly increases the capital and the operating costs for any short sea operation. Thus, it makes SSS more expensive and less competitive. A study in 1993 suggested that the net cost of the Jones Act to the US economy is $4.4 billion US per year [47]. As the idea of SSS is gaining ground, the debate over the Jones Act has been reignited. Defenders of the Jones Act claim that it is way to revitalize the domestic shipbuilding industry, by providing financial incentives for shipowners to build in the US. Shipyard owners claim that they can be competitive for smaller standardized vessel designs with a shipbuilding program for a series of ships to be constructed over the next 15–20 years. On the other hand, shipowners argue that they can purchase

Table 6. Strengths–Weaknesses–Opportunities–Threats (SWOT) analysis of the development of SSS in the US.

Strengths	Weaknesses
• High fuel efficiency (per ton-mile of cargo), economies of scale	• Additional nodes (ports) in cargo flows
• Environmental benefits: fewer emissions, less air pollution	• Terminal handling costs
• Highway congestion mitigation	• Low vessel speed
• Road safety improvement	• Image problem, shippers' reluctance
• Low infrastructure costs, port investment	
• Easy to expand	
Opportunities	**Threats**
• Container trade growth	• Port fees, Harbour Maintenance Tax
• MARAD and EU promotional policies	• More paperwork and bureaucracy
• Intermodal integration, door-to-door, just-in-time practices, modern logistics	• High vessel capital costs (Jones Act)
• Truck drivers' shortage	• More sea traffic strain at ports, incompatible port terminals
• Increasing fuel prices, aliances with trucking industry and port authorities	• Rail competition
• Alleviation of port capacity problems, i.e. feedering	• High levels of SO_2 in marine fuel

SSS vessels from the international ship market for a fraction of what they cost in the US.

From the previously described benefits and obstacles, we can evaluate the internal and external factors for the successful growth of SSS. Therefore, we performed a strategic planning analysis, known as strengths-weaknesses-opportunities-threats (SWOT) analysis. The strengths and weaknesses are the internal factors, while the opportunities and threats are the external factors that influence SSS. Table 6 summarizes the major positive and negative points of SSS that were addressed above in a SWOT analysis framework.

7. SSS as part of intermodal transportation

The numerous SSS conferences and the various surveys in the US and in Europe have revealed that the integration of SSS into the intermodal transportation and logistics chains is imperative for its success. An empirical research study was conducted in 2002 among short sea shipowners in the UK using the Delphi approach, i.e. a systematic collection of informed independent judgements from a panel of experts [48]. They agreed that SSS should be integrated into the intermodal transportation. Similar questionnaires among shippers in the US showed that on-time reliability and door-to-door capability are the leading factors in their choice of transportation mode. SSS should be an integral component of a multi-modal transportation network that will provide on-time reliable service and will meet modern door-to-door and just-in-time requirements. While short sea vessels will take over the long-haul leg of the freight transportation chain, trucks will pick up and

deliver the cargo to the final destinations, i.e. drayage. The trucking industry can be an ally and a complementary mode for SSS. Trucking companies can become partners instead of competitors for the long-haul freight transportation and can further assist the growth of SSS. Facing a shortage of drivers, trucking companies have already expressed their interest in co-operating with shipowners. Successful operations, such as Osprey Lines in the US and Samskip in Europe have showed that working with truckers and becoming intermodal providers were key elements of their success. The business strategies of ocean and rail companies, such as APL and CSX, which became total intermodal logistics providers, should be examined. Furthermore, port authorities are increasingly interested in 'feedering' their international containers to smaller satellite ports, using SSS, as a way to increase their yard capacity and improve their terminal efficiency.

The recent developments in supply chain management and the new trends of globalization, decentralized production and outsourcing of logistics to third party providers can benefit SSS even more. Modern logistics has become an essential part of the production process. Supply chain requirements focus not exclusively on speed, but on time reliability, with just-in-time transportation and zero inventory costs. Combined truck and SSS can take advantage of their efficiency, reliability and flexibility. Door-to-door cargo transportation requires the close cooperation of different modes. New technologies, such as cargo tracking, can facilitate that coordination and increase the level of service. The intermodal terminals as cargo transfer points are a crucial part of the intermodal transportation chain. Supply chain management have led to the creation of central trans-shipment facilities or hub terminals [49]. SSS can exploit all these opportunities in logistics and become a modern form of intermodal transportation. Ports should operate as 'seamless' logistics nodes that will offer high level of service by facilitating the smooth transfer of cargo and the coordination among the different modes. Better communication and information exchange among the various modes is necessary. Itineraries and timetables among them should be synchronized. Fast and efficient cargo transfer is a key for the success of SSS.

The port–ship interface is a critical element in eliminating unnecessary delays and friction costs. For example, automation can reduce both the handling costs and the turnaround time of the containers. Concepts such as 'lean port' and 'crossdocking' can increase the terminal efficiency [50]. Various information technology applications, such as electronic data interchange (EDI) for the commodity flows or intelligent transportation systems (ITS) for port traffic management can be applied as well. In the Saint Lawrence Seaway, an automated identification system has been used as a tool for better traffic control and navigation assistance. The Port of Rotterdam established a successful SSS operation using container barges and state-of-the-art cargo handling technology.

The idea of sustainable freight transportation is also gaining ground among its users, i.e. the shippers, the transportation stakeholders and the public. The negative effects of freight transportation can be reduced by exploiting economies of scale and distance of SSS and thus reduce the external costs per tonne-kilometre. Additionally, by introducing more efficient intermodal transportation and implementing efficient cargo transfers at port terminals that reduces cargo handling time and costs, we can create modal shifts from road to SSS. Network techniques and consolidation of cargo flows can improve the overall efficiency and reduce the total

transportation cost significantly. Innovative bundling, i.e. consolidation, networks have emerged as a way of taking advantage the energy efficiencies of rail and sea transportation for the long-haul part and the flexibility of road transportation for the collection and distribution parts. These intermodal transportation systems are broadly recognized as sustainable and environmentally friendly means of freight transportation [51–53].

8. Conclusions and recommendations

SSS offers many public benefits. Removing heavy trucks from the highways reduces congestion on major trade corridors, contributes to the decrease of road accidents on highways and improves the air quality around the metropolitan areas. Additionally, SSS can alleviate the capacity and efficiency problems at US ports, by swiftly dispatching containers to satellite feeder ports. However, there are administrative and operational barriers. Certain measures from the federal government, such as the waiver of the HMT fee, and from other stakeholders in the transportation industry could facilitate the expansion of SSS in the US. The studies conducted in Europe and in the US revealed many common issues and challenges that should be addressed, in order SSS to be a successful alternative mode for freight transportation.

The negative effects of freight transportation, known as externalities, must be identified, quantified and internalized with approaches and policies designed to promote modal shifts to more sustainable transportation modes. Transportation decisions should be based on a fair and efficient pricing system that will reflect the marginal social costs that also include all the external costs. SSS is a mode with significantly lower external costs than the currently dominant truck mode. Despite the uncertainties in the estimation of such externalities, SSS can prove that it is an efficient and sustainable mode for the long-haul freight transportation.

SSS should be integrated into the intermodal transportation networks. Vessels will take over the long-haul leg while trucks will do the pick-up and delivery at the two ends of the transportation chain. Alliances with trucking companies and port authorities could facilitate such integration. In order to attract shippers and ship-owners, SSS must first prove that it is financially viable. Market research studies and cost-benefit analyses should examine the commodity flows on main trade corridors and identify potential modal shifts, in order to establish successful short sea operations. Transportation cost parameters should be calculated, from start-up capital costs to operating and cargo handling costs, in order to determine the total logistics costs. Given that the society gets the majority of the external benefits of a modal shift from road to SSS, the role of the government should be thoroughly examined, including the several options for financial support from federal or other public resources.

As part of the US marine transportation system, SSS requires additional research in areas ranging from marine engineering and ship design to modern logistics and transportation science. The science of operational research can provide the quantitative tools for optimizing short sea operations and integrating them into the intermodal transportation chain. Transportation network techniques, such as freight bundling networks, adapted for marine applications, can be applied to model the distribution of international containers from the hub ports to feeder ports. The problem of SSS integration can be viewed as a strategic transportation planning problem [54]. The objective could be the design of an intermodal transportation

network with its nodes, links, and vessels. SSS needs customized solutions for every emerging transportation market in congested trade corridors. A 'one-size-fits-all' approach is unlikely to be effective.

The prospects of SSS in the US are promising. Its many advantages can overcome the barriers hindering its growth. SSS offers many benefits to the transportation industry, the society, the national economy and the environment. A few successful existing operations make a strong case in favour of SSS. Its expansion as an integrated intermodal transportation system should be of national interest. Therefore, public and private organizations should collaborate in achieving this goal. SSS can be an efficient, reliable, and environmentally friendly option for relieving highway congestion and increasing the mobility and the capacity of the US transportation network.

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