Green Perspective of General Container Service vs. Dedicated Container Service from Asia to Northern Adriatic

Zelena perspektiva općeg i namjenskog kontejnerskog prijevoza od Azije do sjevernog Jadrana

Marko Golnar*
University of Ljubljana
Faculty of Maritime Studies and Transport Portorož
Slovenia
E-mail: marko.golnar@fpp.uni-lj.si

Bojan Beškovnik
University of Ljubljana
Faculty of Maritime Studies and Transport Portorož
Slovenia
E-mail: bojan.beskovnik@fpp.uni-lj.si

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Abstract

Intermodal transport is often touted as an environmentally sustainable mode of transport, especially when considering its share of the total supply chain. This article addresses the topical and sensitive issue of supply chain assessment in terms of the carbon footprint and energy efficiency of external transportation from the point of production to the customer. The long transportation distances overseas and the variety of operational sea container services result in significant variations in delivery times from Asian markets. In addition, disruptive events such as the Covid-19 pandemic and the Ukraine conflict have led to longer transportation times and lower reliability of various maritime services. The study examines the variety of existing direct container services from Asia to the Northern Adriatic. In addition to the two direct container services already established, another dedicated container service has been established primarily to serve a large retail chain in the European market. The "newly established" container service is characterised by its limited port coverage and the use of relatively small container ships with a maximum capacity of 5.500 TEU. The comparisons between the services highlight the differences in transport time and greenhouse gas (GHG) emissions, as well as the energy efficiency of container transport. The study empirically confirms the widespread assumption that larger and modern container ships offer environmental benefits, provided that cargo space is used efficiently and ship operators adopt slow steaming. However, the study also highlights the significant differences in GHG emissions between different services and emphasises the need for more comprehensive information and awareness among cargo owners to design sustainable supply chains.

KEY WORDS
shipping
supply chain
container service
GHG emissions
energy efficiency
northern Adriatic
slow-steaming

Sažetak

Intermodalni transport često se reklamira kao ekološki održiv način transporta, posebno kada se uzme u obzir njegov udio u ukupnom opskrbnom lancu. Ovaj se članak bavi aktualnim i osjetljivim pitanjem procjene opskrbnog lanca u smislu ugljičnog otiska i energetske učinkovitosti vanjskog transporta od točke proizvodnje do kupca. Duge prekomorske udaljenosti i raznolikost kontejnerskih linija rezultiraju značajnim varijacijama u vremenu isporuke s azijskih tržišta. Osim toga, remetilački događaji kao što su pandemija COVID-19 i sukob u Ukrajini doveli su do duljeg vremena prijevoza i manje pouzdanosti raznih pomorskih usluga. Istraživanje ispituje raznolikost postojećih izravnih kontejnerskih linija od Azije do sjevernog Jadrana. Uz dvije izravne kontejnerske linije, uspostavljena je još jedna namjenska kontejnerska linija koja prvenstveno služi velikom maloprodajnom lancu na europskom tržištu. „Novouspostavljenu" kontejnersku liniju karakterizira ograničena pokrivenost luka i korištenje relativno malim kontejnerskim brodovima s maksimalnim kapacitetom od 5.500 TEU. Usporedbe između linija ističu razlike u vremenu prijevoza i emisijama stakleničkih plinova (GHG), kao i energetsku učinkovitost kontejnerskog prijevoza. Istraživanje empirijski potvrđuje široko rasprostranjenu pretpostavku da veći i moderniji kontejnerski brodovi nude ekološke prednosti, pod uvjetom da se teretni prostor učinkovito koristi i brodari plove smanjenom brzinom. Međutim, u istraživanju su također naglašene značajne razlike u emisijama stakleničkih plinova između različitih linija te se naglašava potreba za sveobuhvatnijim informacijama i sviješću među vlasnicima tereta za osmišljavanje održivih opskrbnih lanaca.

KLJUČNE RIJEČI
brodarstvo
opskrbni lanac
kontejnerski prijevoz
emisije stakleničkih plinova
energetska učinkovitost
sjeverni Jadran
plovidba smanjenom brzinom

1. INTRODUCTION / *Uvod*

One of the key successes of lean and agile supply chains is effective demand response. Shortening transportation distances and minimising the number of stops in supply chains can reduce pressure and improve the efficiency of logistics operations throughout the supply chain. The container industry is seeking to optimise its transportation chains based on the principle of economies of scale, whereby larger vessels with

* Corresponding author

higher cargo capacity tend to call at more ports on a single overseas service. As a result, ship operators are looking to minimise the number of stops on the one hand, and maximise vessel utilisation on the other in order to optimise their operations. The number of key ports at which the container service must stop is increasing and transportation time is lengthening, resulting in longer delivery times.

Disruptive events such as the Covid-19 pandemic have highlighted a number of logistical vulnerabilities, including port congestion, limited availability of shipping space, and increased unpredictability in the delivery of semi-finished products to manufacturing facilities and finished products to retail centres. To some extent, this was also the case in the port of Koper, which influenced lean processes in port logistics [1].

Within the maritime industry, there are multiple objectives that extend beyond the promotion of sustainable international transportation. This evolving industry consistently pursues various goals while placing an increasing emphasis on environmentally friendly transportation practices. Modern ship architecture, the use of clean fuel alternatives, the integration of scrubber systems, and slow steaming are some of the recommendations for sustainable maritime transport. These efforts aim to reduce the global carbon footprint by 70% from 2008 levels by 2050 [2]. One of the main stakeholders in achieving the set targets are the ship owners or shipping companies, as they determine the operational performance, such as the size and age of the ships, the number of ports called in container services, the formation of alliances to achieve higher utilisation of cargo space, and finally the speed of the ships used. Their operational decisions directly impact the operation and reliability of supply chains. Larger ships result in longer port calls, while a greater number of ports called by overseas container services also results in longer travel times. In addition, the introduction of a 40% reduction in vessel speed exacerbates liquidity problems for customers in the container transport sector. Direct container services with a smaller number of ports and smaller ships are emerging as an alternative to existing container services. Among others, the latter are offered in the market by Tailwind Shipping Lines, which targets European retail chains and Chinese consumer goods that need to be delivered to shelves on time. This container service differs from existing overseas container services between the Asian and European markets by offering smaller vessels with a capacity of up to 5.500 TEU, which can conveniently call and berth at smaller ports with lower congestion rates. Ship owners primarily choose ports near major retail centres to shorten delivery times in time-sensitive supply chains [3]. The use of smaller ships and lower ship speed has a negative impact on CO_2 emissions per transported TEU. These increase especially with low cargo space utilisation. The study analyses the time and environmental components of the existing direct container services between Asia and the northern Adriatic. There are 13 container services in the port of Koper, of which post-Panamax ships account for about 31% of all container ship calls [4]. These ships are mainly used on direct container services between Chinese ports and Koper, provided by the shipping companies of two alliances, namely 2M and Ocean Alliance.

The research thesis is that direct dedicated container service offers a time-efficient solution for lean and agile operation of supply chains, but at the same time is significantly less environmentally friendly. Consequently, such supply chains indirectly contribute to an increased carbon footprint, making it important to understand the gap that ongoing services create. The research results show the importance of evaluating the supply chain from a GHG footprint perspective as well. Shorter transportation times on the same routes increase GHG emissions, so stakeholders need to be aware of the different carbon footprints and energy used to transport their goods to the shelves. The next sections are organised as follows. Section 2 discusses previous studies. Section 3 describes the methodology and research approach, while the results and discussion are presented in Section 4. In the last section, conclusions and future work are addressed.

2. RESEARCH BACKGROUND / *Pregled istraživanja*

This section provides a comprehensive review of the existing literature concerning the challenges faced by maritime transport. It examines the uncertainties associated with transportation demand, explores the environmental perspective associated with container services and their decarbonization efforts, and explores optimal ship management strategies with a focus on speed optimization and cargo space utilisation.

Global intermodal transportation chains face several challenges today. One of the most important is the unstable demand for maritime cargo space and the disruption of supply chains, resulting in significant financial losses for companies and unnecessary CO_2 emissions. To overcome uncertainties in supply chains, Kumar et al. [5] developed a high-integrity quantitative model to capture the interrelationships between costs and carbon emissions at all levels of a supply chain and showed that higher variability increases supply chain costs, service levels, and supply chain emissions. In addition, Lee et al. [6] developed a similar model to account for the interrelationships between ship time, bunker costs, and service quality to help shipping companies manage their fuel consumption strategy, improve service quality, and more accurately calculate appropriate buffer times for ports. Instabilities in cargo space demand and supply were addressed by Liu et al. [7], who proposed flexible contracts that would allow dynamic changes in capacity and prices depending on current unstable conditions. Their model accounts for both demand instability and supply chain disruptions, which in turn demonstrates the flexibility and sustainability of container companies. Moreover, Gómez-Padilla et al. [8] proved that option contracts for leasing containers are the best option in the global shipping industry when demand is highly volatile. Several strategies for green shipping can be found in the literature. Inal et al. [9] conducted a comprehensive study to identify viable and effective solutions to achieve environmental goals. The evaluation revealed that hybrid propulsion systems have favourable characteristics such as lower noise, vibration, maintenance frequency, cost efficiency, and lower emissions. This underscores the potential of hybrid powertrains as a promising strategy for achieving environmental goals. In addition, Lindstad and Bø [10] conclude that hybrid power setups combined with slender designs are the most cost-effective solution for the energy efficiency design index (EEDI). The EEDI was introduced by the International Maritime Organisation (IMO) [2] as an emission reduction strategy (SO_x, NO_x, and CO_2) that generally indicates the CO_2 emissions of a given ship per tonne-mile. Shipbuilders and designers responded with various solutions for lower drag ships, which reflected in lower fuel consumption [11,12]. Research conducted by Lindstad et al. [13] unveiled that a combination of more slender bulk carriers with wind-assisted propulsion can reduce greenhouse gas emissions by up to 25%. As another strategy to decarbonize the maritime sector, Elkafas et al. [11] presented the possibility of using fuel cell systems as an alternative to reduce the consumption of primary fuels. In addition, Livaniou and Papadopoulos [14] studied liquefied natural gas (LNG) as one of the alternatives to marine gasoil and concluded that LNG produces 20-30% less CO_2 emissions. The reduction of emissions includes another important aspect, namely exhaust gas treatment techniques, which were thoroughly investigated in the study conducted by Winnes et al. [15]. The focus of their study was on the use of various particulate filters and catalytic converters to reduce sulphur and nitrogen oxide levels. In response to the dilemma of whether fuel switching or scrubber is the most appropriate technology for emission reduction on ships, Gu & Wallace [16] highlighted the cost perspective and the importance of a ship's performance in the emissions control area. The use of a scrubber on ships to mitigate exhaust gases is also an attractive choice from an economic perspective compared to marine gas oil [17]. In addition, Kyaw Oo D'Amore et al. [18] have shown that scrubbers with targeted design can also have a silencer function.

Another strategy to reduce emissions is to operate the ship in an optimal range. A study by Borén et al. [19] on optimizing the routing of ships showed a reduction in emissions of up to 30% on longer routes. Notteboom and Verminnen [20] introduced ship speed reduction as one of the environmental economic measures to reduce the environmental impact. Such a measure is primarily referred to as "slow steaming" (SS) and reduces fuel consumption, which in turn means fewer emissions and a smaller carbon footprint, as well as less noise [21]. The research conducted by Golnar and Beškovnik [22] has shown the significant potential of up to 40% for the introduction of slow steaming in the Adriatic region. Moreover, in their study they emphasize the importance of using this approach wisely, taking into account the complicated dynamics and responsiveness of the supply chain. Furthermore, Venturini's study [23] revealed that emissions could be reduced by up to 42%. A more detailed simulation conducted by Tran and Lam [24] highlighted that vessel speed affects over 70% of the supply chain carbon footprint, but also 50% of the lead time and ¼ of the supply chain cost. Interestingly, Leaper [25] finds that a 10% reduction in speed can lead to an overall energy saving of 40%. Similar conclusions were reached by Andersson et al. [26], who demonstrate that a 30% reduction in the speed of a ship leads to fuel savings of between 2% and 45%, depending on the type of ship, size, and weather conditions. In addition, a study by Maloni et al. [27] indicates that the effectiveness of speed reduction and fuel consumption also depends on the cargo that the ship is carrying. It is noted that for certain cargoes, such as refrigerated cargoes, reduced ship speed is not an option. However, reduced ship speed can also have negative economic consequences, reflected in longer transportation times and lower vessel productivity. In addition, the study by Herrera Rodriguez et al. [28] showed that slow steaming primarily affects shippers with longer lead times, while liners benefits from lower operating costs. This is consistent with the results of Tran and Lam [24], who indicate that shippers pay higher costs for inventory (118% versus 100%) when using an 18.000 TEU ship instead of a 6.000 TEU ship. Such a discrepancy undoubtedly has a negative impact on the competitiveness of container forwarding companies that are therefore tending to use smaller ships rather than larger ones. Similarly, Lee et al. [6] studied the impact of SS and delivery reliability and concluded that to maintain the same service frequency, an additional vessel must be added to the fleet, which was also described by Dulebenets [29] and Cheaitou and Cariou [30]. Consequently, when implementing policies or legislation that propose reduced sailing speeds in any way, special attention must be paid to the interrelationship between environmental benefits and potential economic impacts. The above measures can be a useful offsetting tool and incentive for businesses to reduce their carbon footprint.

Considering that maritime transport is a crucial and difficult-to-replace element of supply chains, it is crucial to prioritize studies on vessel speed and capacity, taking into account financial and environmental impacts. In this study, the problem of appropriate ship size on the Asia - Europe route is considered from an environmental and time perspective that directly impacts supply chains. The results highlight the importance and need for cargo owners to develop environmental awareness when designing their own transport chains.

3. RESEARCH APPROACH / *Pristup istraživanju*

In the study, a rigorous and multi-layered research methodology was applied to investigate the environmental aspects of maritime transport services in the Port of Koper. This methodology included two interrelated approaches: a systematic literature review and greenhouse gas (GHG) emissions calculations.

The systematic literature review was carefully conducted, applying selection criteria to identify relevant and authoritative sources from the fields of liner services, slow-steaming, and environmental impacts of maritime transport. Respected research databases such as Scopus and ScienceDirect were carefully searched to gather a comprehensive range of scientific literature and ensure that the most current and reputable studies were included.

At the same time, comprehensive data on transport prices, transport times and specific shipping routes were collected and processed. These data served as the basis for the accurate calculation of GHG emissions, using advanced methodologies and industry-standard models. The integration of these various data sources allowed for a comprehensive assessment of the environmental impact of shipping from Asia to the Port of Koper.

By applying this research methodology (Figure 1), the study aimed to provide a comprehensive and evidence-based analysis of the environmental dimensions of maritime transport services. The combination of systematic literature review and emissions calculations provided a holistic understanding of the factors influencing sustainability in maritime transport and contributed to the body of knowledge in this field.

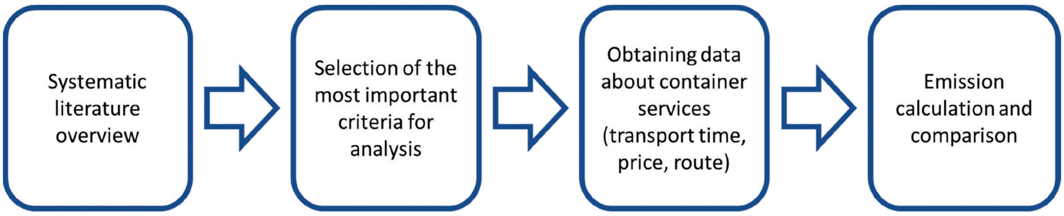

Figure 1 Methodology overview
Slika 1. Pregled metodologije

Source: Prepared by authors

3.1. Data about analysed container services / *Podaci o analiziranim kontejnerskim linijama*

There are some differences in the container services offered by shipping companies that provide direct overseas connections between Chinese ports and the northern Adriatic. There are three direct container services in operation, offered by seven different shipping companies. These are shipping companies from the two largest alliances, 2M and Ocean Alliance, as well as the independent service of the German shipping company Tailwind (DCS), which is part of the ownership structure of the German retailer. Maersk and MSC call at the following ports on the westbound route to Koper (GCS1): Xingang, Dalian, Busan, Ningbo, Shanghai, Shekou, Singapore, Port Said and Haifa. Ships up to 15.500 TEU (such as Maersk Huacho, Maersk Hidalgo, MSC Genova, etc.) operate on the service. On the Ocean Alliance direct container service (GCS2), the shipping companies CMA-CGM, COSCO, Evergreen and OOCL operate together. Westbound departures are scheduled from the ports of Shanghai, Ningbo, Busan, Shekou, Singapore and Malta. Ships with cargo capacity between 8.500 and 10.000 TEU are used for the service (e.g., M/V CMA-CGM Tanya, M/V CMA-CGM Thames, M/V APL Chongqing, etc.) (CMA-CGM, 2023). DCS operates its own direct service from Chinese ports to Koper under the name Panda Express. The westbound voyage for POD Koper starts in Taicang (Shanghai), then the ship calls at Qingdao, Ningbo and finally Da Chan Bay (Shenzhen). Thus, the ship calls at only four Chinese ports in the westbound voyage. Ships with a cargo capacity of 3.800 to 5.500 TEU (M/V Merkur Ocean, M/V Jadran, M/V Panda 001, etc.) are used [3].

The identified data on services, ships, ship travel time on a given service, and ship speed were collected during the period January - April 2023. The data is subject to change as it is a dynamic part of the planning and execution of maritime transport processes, often subject to commercial-operational decisions by ship owners.

3.2. Data analysis / *Analiza podataka*

The research includes an analysis of two elements of the operation of maritime container services from the point of view of supply chain support. This is an important element of transportation time, which is critical to the operation of lean and agile supply chains. The importance of considering time windows for container ship operations is explained by Ng [31] in his study. In our study, three services are analyzed, with transportation times from three Chinese loading points, namely Shanghai or Taicang, Ningbo, and Shekou or Shenzen. The transportation times are summarized according to the shipping lines' published schedules and are publicly available on their websites. When checked with the data in the port of Koper, there are possible discrepancies that occur within one or two days for all shipping companies. The green approach element of the maritime transport analyzes the carbon footprint, NO_x and SO_2 emissions, and energy efficiency of container transport. The online EcoTransIT Environmental Calculator tool is used to compare the three container services, based on a methodology consistent with the requirements of the EN 16258 standard and the GHG Protocol. The tool is already widely used by various NVOCC operators. The calculator was developed by a consortium of the scientific institute Ifeu, INFRAS and Fraunhofer IML [32]. The calculation of emissions and energy efficiency in the maritime industry is usually based on a unit of 20-foot containers, also known as 1 TEU. Here, the average weight of 14 tons for 20-foot containers is used as a standardized measure for the mass of transported goods. According to the parameterization of the calculator, the following categories of ships are used for the calculation: ULCV - ships over 14.500 TEU, Suez-max - ships with a carrying capacity over 7.000 TEU, and Panamax - ships with 3.500 to 4.700 TEU capacity.

It is difficult to accurately estimate the occupancy of container ships along the entire transport route because the three services under study call at a different number of ports and the ships are gradually filled to final capacity. Moreover, the ships of the GCS1 service unload part of the containers in Port Said and Haifa, which means that the ship sails to Koper with a lower load factor, even if part of the containers for Koper are loaded in these two ports. Similarly, the vessels of the direct container service GCS2 stop in Malta, which is an important hub port, and unload part of the containers there. For a comparative analysis of the different maritime services, it is important to look at the utilisation of the cargo space. It can be observed that ships often continue their voyage to Koper with a lower utilisation rate. However, according to DSF (2019), the average load factor for the Asia-Europe trade before the pandemic was around 80%, which is usually sufficient for ship owners to make operating profits. Therefore, it is reasonable to use this utilisation rate as a benchmark for evaluating the efficiency and profitability of different container services. In the case of the DSC container service, a higher utilisation rate of 90% is used as the ships consistently have high utilisation rates throughout the voyage from Asia. In addition, due to their lower capacity, these values are better suited to achieve a higher utilisation rate. Travel speed is important in calculating GHG emissions. Ship owners use slow speeds between 20% and 40%, meaning they travel at an average vessel speed that is 20% to 40% below the maximum available. Data from the Marinetraffic database [33] were used to verify ship speeds in the services. All ships in each service maintained a reduced speed between 15 and 18 knots. Therefore, a 30% speed reduction, known as slow steaming, was included in the emissions calculation.

4. RESULTS AND DISCUSSION / *Rezultati i rasprava*

The analysis of travel times between POL Shanghai/Taicang, Ningbo and Shekou/Shenzen and POD Koper shows large differences between the three connections studied. According to the available data for the period February - April 2023, the TT on the direct DCS container line is the shortest. It is longest from Taicang port and is 28 days, as the Panda Express service starts its westbound journey from this port. TT from Qingdao is 25 days, from Ningbo 22 days and from Shenzhen only 19 days. The GCS1 container service offers a competitive TT from Shangai due to its unique westbound route. From Ningbo, the service heads towards Shanghai before continuing its journey to the port of Shekou. This routing allows for efficient and timely transportation, making it an attractive option for customers seeking reliable and relatively fast delivery of their cargo. The least time competitive container service is the GCS2. Unlike the DCS service, the TT from Shanghai to the destination port is 21% longer. Similarly, the TT from Ningbo is 50% longer, while the TT from Shekou is twice as long (Table 1).

Undoubtedly, DCS offers shorter transportation times in supply chains. Transport customers can reduce delivery times for the European market by 30 to 50% or by a good week. For larger container volumes and regular weekly shipments, this is clearly reflected in the improvement of the liquidity of the business of maritime container transport customers. Since TT is only one of the elements that modern supply chains deal with, the environmental aspect of a shorter and faster maritime service must also be considered. Namely, smaller ships certainly spend less time in ports, as up to four times less manipulation is required for the ships with full cargo capacity. Moreover, it is well known that smaller and older ships emit larger amounts of CO_2, SO_2, and NO_x emissions per container transported than larger and newer ships. By comparing the energy efficiency

Table 1 Comparison of TT between direct services from China to POD Koper

Tablica 1. Usporedba vremena prijevoza na izravnim linijama iz Kine do luke iskrcaja Kopar

Carrier	POL		
	Taicang/ Shanghai	Ningbo	Shekou/ Shenzen
Dedicated container service	+3,5%	0	0
General container service 1	0	+ 36,4%	+ 31,6%
General container service 2	+ 21,4%	+ 50,0%	+ 100,0%

Source: Prepared by authors

of transportation and GHG emissions, we can determine the difference between the services and what negative impacts are associated with the choice of container services. According to the data collected, the difference between container services on DCS and GCS1 is very pronounced. Even with higher utilisation of cargo space on DCS service, energy consumption per transported TEU is 150% higher (Figure 2). Compared to GSC2, the EE of the DCS service is 27% higher for all three POLs studied. Of course, the relationships between the services should be taken with caution, since the mean values of the ships are used in the calculation, while the services use different ships with different capacities, which is especially true for the GCS2 service. This service occasionally uses ships whose size is not significantly different from the size of the ships in the GCS1 service, so the differences between the two services in EE are smaller in this case.

DCS container service is also the least environmentally friendly in terms of carbon footprint, according to EWT. CO_2 emissions from POL Ningbo are 170% higher compared to the GCS1 service (Figure 3). Similarly, POL Shanghai has a slightly lower difference (149%) and Shekou 148%. The difference is also evident when comparing the carbon footprint between GCS1 and GCS2 services. GCS2 generates 112% more CO_2 emissions from Ningbo, 97% from Shanghai, and 95% from Shekou. The difference in the CO_2 footprint of a transported container on the DCS and GCS2 services is just over 26%.

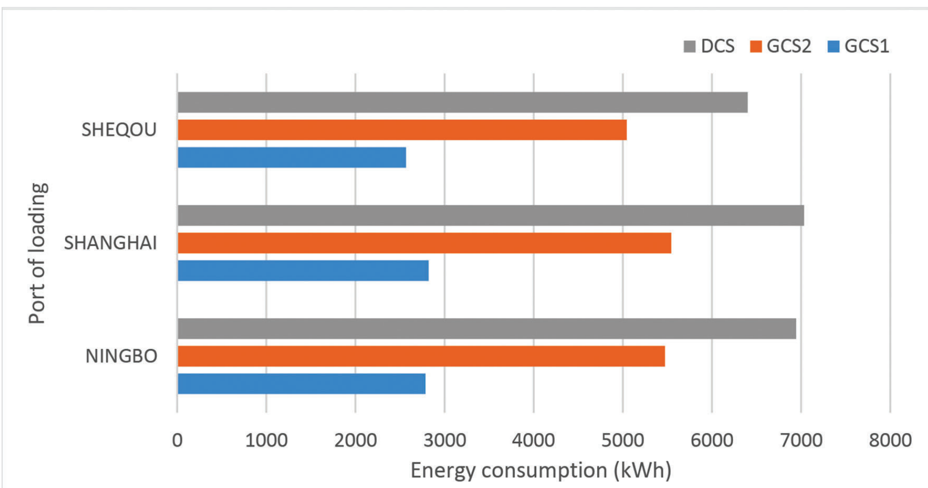

Figure 2 Energy consumption by container service from selected POLs

Slika 2. Potrošnja energije po kontejnerskoj liniji za odabrane luke ukrcaja

Source: Prepared by authors

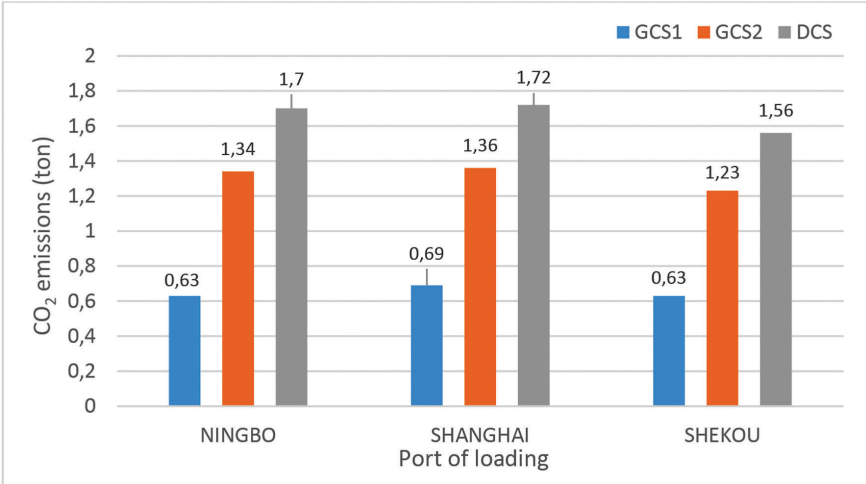

Figure 3 CO_2 emissions by container service from selected POLs

Slika 3. Emisije CO_2 po kontejnerskim linijama za odabrane luke ukrcaja

Source: Prepared by authors

Because SO_2 and NO_x emissions are emitted in a similar proportion to CO_2 emissions, only in much smaller amounts, the DCS service is less environmentally defensible than the GCS1 and GCS2 services. Based on research, it was found that the DCS service emits about 10 kg of SO_2 in transporting containers from POL Ningbo and Taicang to POD Koper, while the SO_2 emissions from POL Shenzen are about 9,5 kg. The SO_2 emissions from POL Ningbo are 141% higher than the GCS1 service and 21% higher compared to the GCS2 service. The estimated differences in NOx emissions are even higher. NOx emissions from POL Taicang are about 33 kg for the DCS service and 154% higher than for the GCS1 service. At the same time, these emissions are 27% higher than the GCS2 service (Figure 4). Similar to the results from EE, the differences in CO_2, SO_2, and NO_x emissions between the GCS1 and GCS2 services should be viewed with moderate caution given the size of the ship deployed at each weekly call at the Port of Koper.

The results of the study on DCS and GCS container services from Asia to the northern Adriatic confirm common assumptions about more environmentally sustainable maritime transport with larger container ships. In particular, the results highlight an important difference between the services that requires a broader consideration of supply chain formation. The pursuit of leanness and agility, based on inventory reduction and rapid transport from production to customer, may be much more harmful from an environmental perspective. The TT and GHG emissions results from POL Taicang demonstrate the need for special treatment. The TT of the DCS service is as much as 3.5% longer than that of the GCS1, while the goods transported in a container cause a 149% higher carbon footprint. SO_2 (138%) and NO_x (154%) emissions are also similar. When transporting containers from Shenzhen, the TT on the DCs service is much shorter and even half as short as on the GCS2 service. The supply chains are certainly much more time efficient. Goods reach the buyer within three weeks after the container is loaded on POL. Goods loaded into a container on the GCS2 service from POL Shekou are in transit for a good five weeks, and customers cannot receive the goods until six weeks after they are shipped

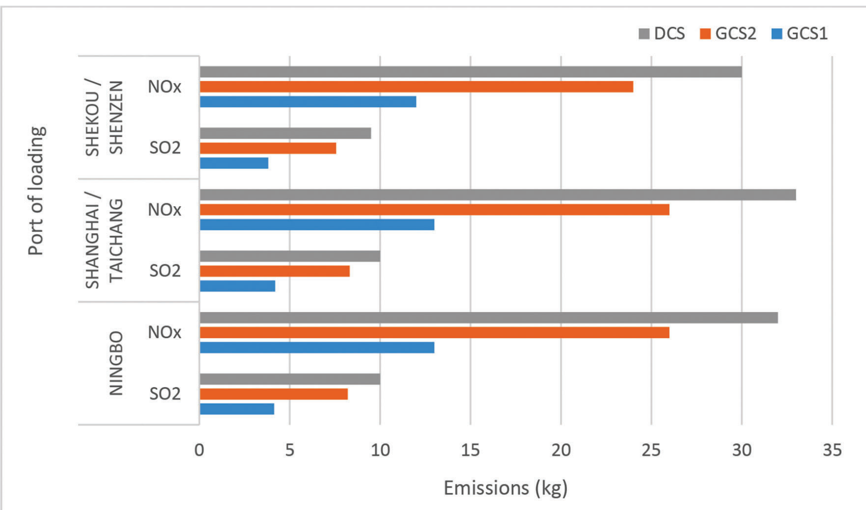

Figure 4 SO_2 and NO_x emissions by container service from selected POLs

Slika 4. Emisije SO_2 i NO_x po kontejnerskim linijama za odabrane luke ukrcaja

Source: Prepared by authors

from Asia. However, such transportation produces around one-third fewer CO_2 emissions and is also more energy-efficient. The study's findings highlight the importance of looking at supply chain design in a broader context that must also pursue more environmentally sustainable business decisions. In doing so, it is important that customers are adequately informed about the GHG emissions potentially generated, as they can decide between the need for transportation and more environmentally friendly transportation. The emission results should be considered as an approximation of real data, as some parameters are generalized and the values used were estimated based on previous studies. This is especially true for vessel utilization, which varies periodically, and for the degree of slow speed. The differences between shipping companies and their services may be larger or smaller, as there are major mutual differences in used ship's capacity, its load factor, and sailing speed. The study therefore uses uniform parameters to allow a direct comparison of the services and, above all, to reflect on the need to evaluate the supply chains also in terms of the chosen environmentally friendly mode of transport.

5. CONCLUSION / *Zaključak*

Greener maritime transport is one of the main goals of most maritime industry players. Even if more important goals are set for the year 2050, it is necessary to take only incremental important steps to achieve them. One such measure that both logistics companies and container shippers need to develop together is a more comprehensive assessment of container transportation. Most importantly, in addition to the elements of price and time of transport, the GHG emissions generated and the energy efficiency achieved by the container transported are particularly important.

The results of the study underline the need for such an approach, as they confirm the established research thesis that direct dedicated container service is more efficient in terms of time, but at the same time generates significantly higher GHG emissions. Even though such containerized transportation is attractive to the owners of the goods as it offers a time-efficient solution for lean and agile supply chain operations, it also places a greater burden on the environment. The main focus is on the significantly larger carbon footprint and lower energy efficiency of the transport.

While the timeframe of the study is limited to the first quarter of 2023, and thus may not provide comprehensive overview, the findings align with prior research highlighting the significance of slow steaming ant the utilization of larger container vessels. At the same time, the results of the study enrich the field of consideration of the use of intermodal transport in the planning of complex supply chains across the northern Adriatic. The major differences between container services need to be presented to cargo owners in a way that is both representative and transparent. Some large multinational companies have already decided to rate their products based on the carbon footprint generated during their production. Since transportation distances from the point of production to the point of consumption are long, the emissions generated by transporting products to the final market also have a significant impact on the overall carbon footprint of the product. Recognizing the differences between the various maritime transport services can lead to greater awareness among cargo owners and the use of more environmentally friendly modes of transport. This also applies to overseas container services.

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