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Port-2-Port Communication Enhancing Short Sea Shipping Performance: The Case Study of Cyprus and the Eastern Mediterranean

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Abstract: The sustainability of Short Sea Shipping (SSS) is central to a clean, safe, and efficient European Union (EU) transport system. We report on key challenges for advancing reliability, quality, and safety, and removing unnecessary costs and delays at SSS hubs, with a particular focus on Cyprus and the Eastern Mediterranean. Specifically, we consider the effect of port-2-port (P2P) communication on port efficiency by investigating the factors influencing the various waiting times at the Port of Limassol, both from a qualitative and a quantitative perspective. The qualitative results are based on the views of key stakeholders involved in the port call process. The quantitative analysis relies on data from over 8000 port calls during 2017–2018, which are analyzed with respect to ship type, port of origin, and shipping agent. The calculated Key Performance Indicators (KPIs) include arrival punctuality, berth waiting, and berth utilization. The analysis clearly reveals considerable variation in agent performance regarding the KPIs, suggesting a lack of attention to the social aspect of a port's socio-technical system. We propose measures for improving agent performance based on the principles of Port Collaborative Decision Making (PortCDM), including P2P communication, data sharing and transparency among all involved in a port call process including the agents, and open dissemination of agent-specific KPIs.

Keywords: short sea shipping; port-2-port communication; port efficiency; waiting times; shipping agents; socio-technical systems; PortCDM; Port of Limassol

1. A Socio-Technical Perspective

Shipping is a self-organizing ecosystem. Without centralized control, the many players negotiate a multitude of arrangements to meet the variety of services required to support the movement of goods and passengers by sea. Managing these many arrangements means that a port is also a socio-technical system [1,2] because humans and technology continually interact with each other to deliver services. For example, a pilot interacts with a ship's captain to determine a vessel's path, and the captain then navigates the ship using a computer-supported interface to the engine and steering system. Technology gives a certain consistency to the action of objects, such as a ship and terminal cranes, within a harbor, but all are ultimately subject to human control, though this is diminishing with the ongoing increase in automation. While the technical aspects of a system typically display consistent behavior, the social

aspects are less predictable because humans vary in their skills and knowledge of multiple dimensions, such as intellectual capacity, social skills, and specific education.

A self-organizing system operates without central control, which can make it difficult for industries so structured to tackle global problems, such as sustainability. There is no authoritative figure who can dictate change and the most major actions affecting multiple parties need to be negotiated. However, there are sometimes actors who play a key role in managing specific resources, whose decisions can positively influence outcomes for the entire ecosystem, including advancing its sustainability.

In a port, shipping agents play a pivotal role in the use of resources because they negotiate and monitor agreements for shipping companies with those who provide ships with port services. Hence, their decisions directly affect the efficiency of a port. Furthermore, efficient ports contribute to ecological sustainability because faster turnarounds mean less energy is used waiting for port resources, and quicker turnarounds can reduce the overall need for ships, which means less energy is used in their construction. In principle, higher resource use is a pathway to a sustainable world.

Shipping agents are arguably the key component of a port's social system because they engage with many of the other players. Thus, we can think of a port as consisting of a system of engagement centered around agents' interactions with others and multiple systems of production [3], such as piloting, berthing, and container handling. These two systems reflect the social (engagement) and technical (production) nature of a port. Systems of production are following the long arc of automation to becoming increasingly technical. Consequently, wider variation in the performance of the social system, with respect to the technical, is likely for two reasons. First, humans are not machines, and their performance varies. Second, humans are increasingly left to undertake the complex and often unpredictable tasks not easily automated.

Attempts to improve Short Sea Shipping (SSS) performance must consider both the social and technical systems operating within a port. A myopic focus on automation ignores the opportunity to provide better tools and education to enable agents to improve their information accessibility and enhance their information processing capabilities and their competencies. Thus, in this study we look for evidence of shipping agent performance variation to support our contention that there is need to invest in the parallel development of systems of engagement and production. Assisting agents to engage more easily with shipping companies and port service providers, and giving agents better information and decision support systems (DSS) should boost their efficiency and that of the port.

We first review the literature on SSS to understand the context within which the socio-technical system operates, we then analyze data related to SSS using Limassol as a hub, we follow with a discussion on how Port Collaborative Decision Making (PortCDM) is a means for enhanced data sharing and collaboration that can raise the performance level of shipping agents, and we conclude with some recommendations.

2. Review of Related Literature on SSS

2.1. Definition of SSS

There is no standard, unequivocal definition of SSS. The European Union (EU) defines SSS as the movement of cargo and passengers by sea between ports situated in geographical Europe or between those ports situated in non-European countries with a coastline on the enclosed seas bordering Europe [4]. However, in the case of the United States, the Maritime Administration defines SSS as commercial waterborne transportation that does not transit an ocean and uses inland and coastal waterways to move commercial freight. SSS is considered by some as a competitor to road transport [5], and hence they only refer to those corridors that have a land alternative. For the purposes of this paper, we will use the EU's geographical definition of SSS. Please note that according to this definition, more than 90% of the overall waterborne traffic using the Limassol port can be classified as SSS.

2.2. SSS in Europe

Considering the current worldwide SSS situation, many governments support the economic and ecological analysis, which states that SSS outperforms all other comparable transport modes from an environmental perspective. Thus, different policies have been implemented to promote SSS corridors on a worldwide basis [6–9].

In Europe, according to the goals set by the European Commission, SSS should constitute an alternative to road transport, either as part of an intermodal transport chain or as a fully substitutable mode, depending on the type of corridor. Problems such as congestion, pollution, and other environmental aspects have encouraged the development of emission reduction transport policies. Furthermore, competition issues have arisen with respect to the unbalanced modal split in the freight transport market, where road transport absorbs around half of the total market. The main goal is that by 2030 at least 30% of what is currently carried as road freight traffic over a distance of 300+ km will be shifted to other modes, such as rail or SSS and that this figure will be 50% by 2050 [10].

The European Commission asserts that SSS offers a set of advantages that no other mode can provide within the EU, especially in relation to the environment, an observation supported by the previously cited literature. In [11], the strengths and weaknesses of SSS are presented and analyzed. Strengths include geographical advantages (the EU has a coastline in excess of 67,000 km and 60–70% of its industrial and production centers are located within 150–200 km of the coast), financial advantages, human resources, energy advantages, environmental advantages, underused capacity for expansion, and employment opportunities. SSS disadvantages lie in the areas of port operations, corporate culture and structure, innovation, information systems, marketing, and customer service approaches. In [12], the main determinants of SSS success and the limits to its development are discussed by focusing primarily on the European case. These are grouped in three categories: (i) environmental (external costs of road freight transport associated with air pollution, infrastructure, noise, and congestion), (ii) operational (distance, product, and type of ship), and (iii) infrastructure (administrative and port characteristics). Sea transport is one of the most sustainable and economically competitive modes of transport compared to road and rail transport. By including the private and external costs into the total transport cost, SSS has a genuine economic advantage in relation to the road transport system. SSS can alleviate traffic congestion and enhance economic development by maintaining freight flow efficiency; however, it first needs to show a clear advantage for the carrier, either in terms of cost or time saving.

Considering the advantages of SSS and its potential role in intermodal worldwide freight, the EU has developed several different policies in recent years with the aim of promoting intermodal competition through different measures and tools. These include various EU communications, such as two white papers: "European Transport Policy for 2010: Time to Decide" in 2001, and "Roadmap to a Single European Transport Area: Towards a Competitive and Resource Efficient Transport System" in 2011, as well as the program for the promotion of SSS in 2003, through which SSS Promotion Centers were founded in 13 European countries. Furthermore, these include EU programs such as the Pilot Action for Combined Transport (PACT), Marco Polo I and II, Galileo and Trans-European Transport Network (TEN-T), which have been designed (with slight differences among them, in terms of time and specific objectives) to promote different (and socially preferred) modes of transport and intermodality [13]. Within this framework, Motorways of the Sea (MoS) is one of the TEN-T initiatives that aim at introducing new intermodal maritime-based logistics chains in Europe to bring forward SSS as "a real competitive alternative to land transport." All three programs have been promoting SSS by giving support to companies with a project to transfer freight from road to rail or SSS routes or inland waterways.

Nevertheless, with a total budget of €895 million (considering the three aforementioned programs), the EU measures have not yet attained the proposed goals [13]. It seems that the EU policy has not stimulated major observable differences regarding the modal split. A possible explanation is provided in [14], which raises the hypothesis that SSS has not been well defined in the EU, and the market potential for the modal shift from land to sea has been overestimated. According to the

authors, the EU geographical definition may be accepted, but it does not correspond to the purposes of its programs oriented to the modal shift from road to sea. More specifically, while the performance of SSS has been in line with that of road transport, a deeper analysis of cargo flows reveals that this corresponds mainly to captive cargo that could not be shipped otherwise. Seaborne traffic in direct competition with road transport is very limited, especially for containers and RO-RO traffic held in captive traffic where there is no direct road competition.

2.3. Environmental Sustainability of SSS

CO_2 emissions from maritime transport currently represent around 3% of the total annual anthropogenic greenhouse gas (GHG) emissions, which are expected to increase by 150–250% until 2050, in business-as-usual scenarios, due to an estimated tripling of the world trade [15]. Achieving the 1.5–2 °C climate target, as set by the Paris Agreement, requires net zero GHG emissions across all economic sectors, including shipping. Consequently, the maritime sector is facing the challenge to significantly reduce its GHG emissions, as a contribution to the international ambition to limit the effects of climate change. As a result, much recent literature focuses on measures and policies for attaining these reductions.

The technical possibility of achieving the 1.5 °C goal of the Paris Agreement, is examined in [16] through a model-based impact assessment. The authors consider three possible measures to achieve decarbonization of international shipping by 2035: (i) technological (ship material and design), (ii) operational (lower speeds, ship size, and ship-port interface) and (iii) alternative fuels/energy (biofuels, synthetic, LNG, fuel cells, electric, wind). Using a combination of the available measures, they then present four different decarbonization pathways that can create a possible 82–95% reduction in CO_2 emissions by 2035. The study in [17], also shows there is a significant potential for cost effective CO_2 emission reduction for the shipping industry, both in the current fleet, and towards 2030. The study uses a new integrated modeling approach, combining activity-based emission modeling, which includes 25 emission reduction measures with a future fleet development model. In [15], a comprehensive overview of the CO_2 emissions reduction potentials and measures is presented based on a review of around 150 studies published in the literature following the Second IMO GHG Study from 2009 [18]. According to the reviewed literature, emissions can be reduced by more than 75%, based on current technologies and by 2050, through a combination of measures (both technical and operational), if policies and regulations are focused on achieving these reductions. An example of such a regulation is the IMO's Energy Efficiency Design Index (EEDI), which is now applicable for all vessels built after 2013, and puts thresholds on the CO_2 emitted per ton of goods transported for a fully loaded vessel as a function of its size and its type.

The effect of environmental aspects relevant to SSS and MoS, in particular with respect to modal choice, is examined by the study in [19]. The author proceeds to estimate the environmental costs of several routes of the Spanish MoS, using the values the EU provides to calculate the external costs for the Marco Polo freight transport proposals (2013). The results indicate than in two thirds of the cases (48 out of 72) the maritime intermodal option involves lower environmental costs; but, importantly there are also 24 routes where the road option is environmentally preferable due to greater distances in some cases and faster speeds in others, mainly for passenger transport, to keep transit times down to an acceptable level. As the author points out, one of the theoretical advantages the literature attributes to SSS over road freight transport is lower fuel consumption, which depends on relatively low speed; these benefits might be erased, however, when high-speed vessels are used. Therefore, from the shipping industry's perspective, it is necessary to enhance energy efficiency (lower fuel consumption, use of cleaner fuels, etc.) to retain this advantage. The importance of achieving energy efficiency for vessels in SSS is also highlighted in [20], as energy costs are on the rise in this sector, not only due to increasing costs of crude oil, but because of more strict requirements on sulfur content in marine fuel in designated Sulfur Emission Control Areas (SECAs). Compared to deep-sea shipping, SSS is also exposed to competition from other means of transport, such as rail or truck transport. There is

thus a risk that increased energy costs could cause a modal shift of cargo to land-based transportation, effectively increasing the total environmental impact. In [21], the aim of this study is to identify factors influencing SSS operators pricing policies for both the sea and the inland part of the intermodal chains. Interest is concentrated in the Mediterranean area, which is experiencing extensive use of SSS (not feeder) for cargo and passenger transport. Based on interviews with 15 SSS operators (mostly Italian), fuel cost is the most important element influencing the variation in both costs incurred and pricing policy. Other factors involve port costs and market drivers. Finally, the origin and destination of the goods influence the choice of provided service (door-to-door or port-to-port) for most of the operators.

2.4. Port Efficiency and Time in Ports

As nodes within maritime transport networks, ports are crucial to the success of many of the available intermodal options [5]. Frequently, however, they either constitute or are perceived as constituting bottlenecks that reduce the competitiveness of maritime corridors [22]. According to [12], this can be attributed to the frequent lack of good road and rail links to ports, the low adaptability of port capacity to SSS, a low level of reliability and the non-coordinated administrative formalities. The authors discuss desired characteristics of a SSS port and pose the question of whether SSS services should share port facilities with conventional shipping or have separate ones. In any case, a port must avoid bottlenecks in the transport chain and give priority to SSS types of traffic for SSS to thrive. To become a hub, a port needs to be elected as port of call by a large shipping company or mega-alliance and be able to offer large capacities of container handling and storage, lower cost, high reliability, and efficient connections with other transport systems.

Aggressive pricing of port services and efficient vessel and berth scheduling (see for example [23–25]) can raise the competitiveness of a supply chain that includes a sea leg, and this is line with the European policy for promoting SSS. According to [26], port charges make-up 40–60% of overall transit costs in SSS, whereas port charges in deep-sea transport are only 5–10% of the costs; thus increasing port efficiency by reducing waiting and turnaround times is important for reaching the goal set by the EU. Within this context, the appropriate analysis of port efficiency, therefore, becomes an absolutely necessary prerequisite to identifying the port-centric factors that crucially influence the success or failure of policies to promote more sustainable freight transport and to inform future policy on such matters. Thus, maritime transportation policy needs to focus on port efficiency when attempting to promote SSS. An efficient port has the scope to charge higher prices if it provides faster and more reliable services or if it allows the shipper to save elsewhere in a supply chain [22].

Port efficiency studies have traditionally focused on factors such as size, or value of the labor force, or the number or value of capital items, as inputs into the port production process, with quantities (typically couched in terms of Twenty-foot Equivalent Units (TEUs)-containers or tons) as the product of the production process. A survey of port efficiency studies [27], divides the findings into two main approaches: non-parametric Data Envelopment Analysis (DEA) and parametric Stochastic Frontier Analysis (SFA). The emphasis is on the measurement methodologies, the variables used and the results in terms of various port activities as well as on relevant dimensions such as port size, ownership, and location. A main conclusion is the need to better describe the port activity for which the efficiency assessment is conducted and to collect more data from the relevant authorities. In [28], the authors apply both DEA and SFA approaches to study the efficiency of the container port industry for the world's largest container ports (ranked in the top 30 in 2001). For the efficiency analysis, the inputs used include the total quay length, the terminal area, the number of quayside cranes, the number of yard gantry cranes, and the number of straddle carriers, while information on labor inputs is determined from a pre-determined relationship to terminal facilities. The output used is the container throughput.

In the aforementioned analyses of port efficiency, the *time in port* has not been explicitly considered, quantified, or linked to the output of the port production process. Even though it is generally accepted that the time a ship spends in a port can be a significant determinant of that port's competitiveness and, therefore, of maritime transport itself, particularly in the case of intermodal freight movements

and SSS, we found only a few attempts in the literature where the time in ports is actually investigated. In [5], through the development of a conceptual and theoretical model, the direct use of the time in ports as a suitable measure for port efficiency analysis is proposed, and a methodology is described for evaluating the efficiency of SSS ports or terminals on this basis. In [29], it is shown that even with a conservative reduction of the time in port between 1–4 h and with a corresponding speed reduction at sea, the potential for increased energy efficiency was between 2–8%. The paper analyzes a case study using both qualitative and quantitative data of a short sea dry bulk shipping company that mainly operates in the North and Baltic Seas. A port's time efficiency is identified in [30] as one of the most important determinants of waterborne transport costs. The study uses Principal Component Analysis (PCA) from a survey conducted at 41 port terminals in Latin American ports mainly handling general containerized cargoes. In [26], port pricing structures that enhance ship efficiency (i.e., cargo carried per deadweight ton per period) are discussed by providing incentives for reducing the turnaround time in port and the time waiting for port access. A theoretical intermodal competition model is used in [13] to compare alternative modes–road transport vs. SSS. The model includes a parameter related to various port inefficiencies that comprise port access time, ship waiting time in port (due to, for example congestion), customs, and other documentation and administrative procedures, as well as hourly container load and unload rates.

2.5. Summary and Contribution

SSS offers a set of advantages that no other mode can provide within the EU, especially in relation to the environment. The ecological sustainability of SSS, however, relies on port efficiency and the time spent in ports for realizing its advantages as compared to other modes of transport. In the literature on port efficiency, there is a gap in quantifying the different waiting and idle times during a port call process, as well as identifying their root causes. In this article, we consider the effect of time in port by investigating the factors influencing the various waiting times at the Port of Limassol both from a quantitative and a qualitative perspective. In particular, based on our findings, the performance of a shipping agent can be directly linked with reducing these waiting times and thus improving port efficiency. As far as we know, this is the first time that shipping agents are considered as a factor influencing port efficiency. Thus, we redress the lack of attention to the social aspect of a port's socio-technical system.

3. Short Sea Shipping in the Cyprus Context

In this article, we particularly focus on Cyprus, which is an EU member and an island in the Eastern Mediterranean Sea, with an important role to play in improving the efficiency and sustainability of SSS in its vicinity. In particular, more than 90% of its seaborne transport is currently SSS. As an accredited transshipment hub, Limassol could be a focal point for large shipments from other countries. Cargoes could be consolidated and sent to Cyprus, from where they could be efficiently distributed to various nearby ports, such as those in Egypt, Israel, and other countries in the Middle East, using smaller vessels and SSS operations.

3.1. Cyprus in the International Maritime Sector

Cyprus, established as an international shipping center about 55 years ago, has managed to attract shipping companies due to its excellent maritime infrastructure, and a high level of expertise, particularly in the fields of surveying, ship-brokering, and maritime insurance. Today, the Cyprus Registry is classified as the 22nd largest merchant fleet globally and the 3rd largest fleet in the EU, with approximately 900 ocean going vessels of a gross tonnage exceeding 49 million tons. It is estimated that approximately 4% of the world's fleet and around 20% of global third-party ship management activities are controlled from Cyprus. For companies established in Cyprus, around 87% are controlled by Cypriot and EU interests. The island's ports have developed purpose-built container terminals and Cyprus is one of the first countries of the Eastern Mediterranean to use specialized gantry cranes.

Moreover, the island is now considered one of the most important cruise centers and transportation hubs in the region. The Cypriot Government's vision is to develop initiatives that will further expand Cyprus's role as a communication bridge between the EU and the countries of Middle East, such as Egypt, Jordan, Lebanon, and Israel. In addition, the interest of major shipping organizations in using hub ports in the region has increased the need for upgrading the physical and digital infrastructure for providing more cost-efficient services.

The geographical location of Cyprus encourages the use of its ports as transshipment hubs for SSS (see Figure 1). Another favoring factor is also the political stability of Cyprus relative to several countries in the region. Cyprus is expected to become a shipping knowledge center, both exchanging information with steaming ships in the Eastern Mediterranean region for optimizing their routes and avoiding possible hazards, and with other ports in the region to enhance the planning horizon among the stakeholders within the port.

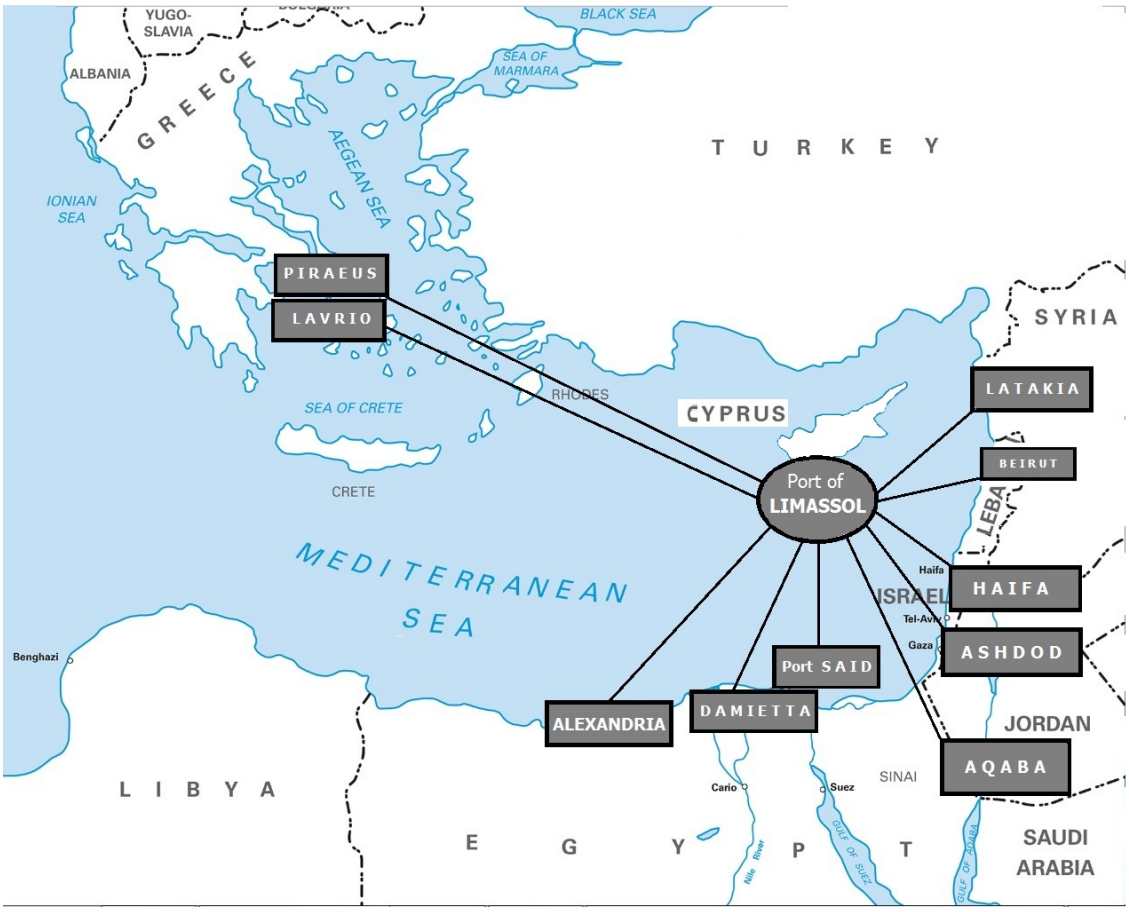

Figure 1. Limassol EU Port in the Eastern Mediterranean [31].

3.2. Port of Limassol and the Importance of P2P Communication

To be a successful transshipment hub, a port should be able to plan its operations precisely and ensure that relevant data are available to visiting ships as well as to neighboring ports. This is particularly important for Cyprus as the distances between Limassol and its neighboring ports are quite small. Figure 2 shows an analysis by region of the traffic from and to Limassol for the years 2017–2018, while the detailed traffic patterns between Cyprus and the countries in the Eastern Mediterranean is depicted in Figure 3 for the same time period.

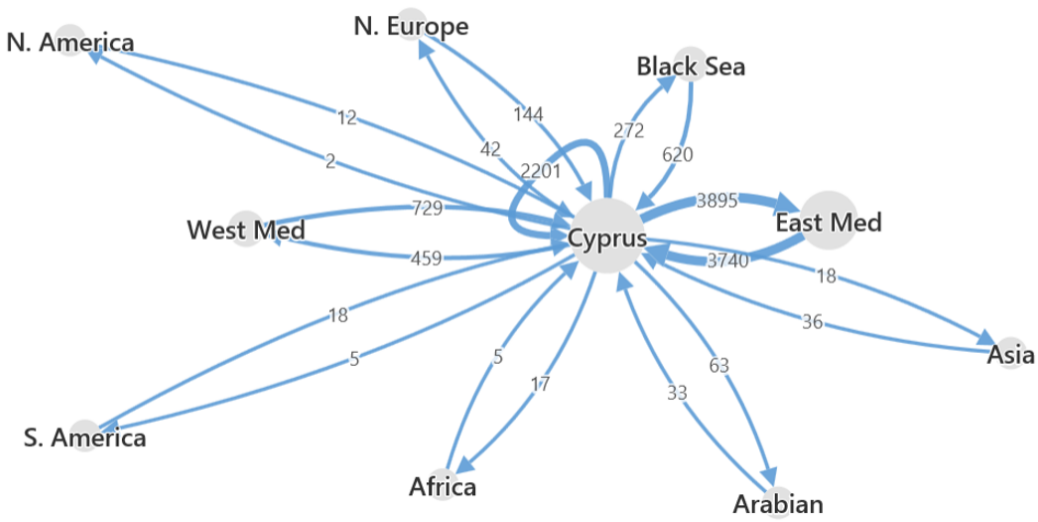

Figure 2. Traffic to the Port of Limassol from various regions and vice versa.

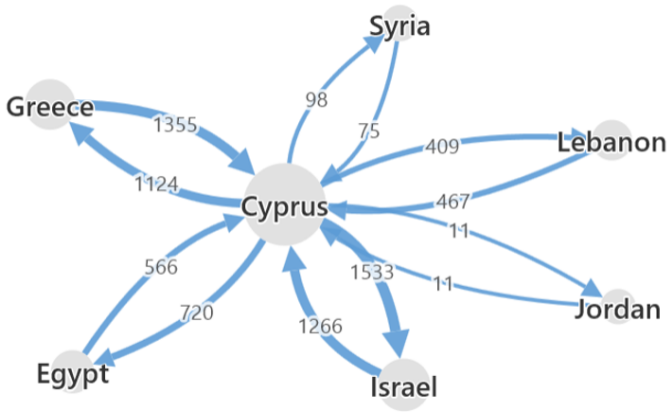

Figure 3. Traffic to the Port of Limassol from various countries in the Eastern Mediterranean and vice versa.

Port of Limassol has over the last three and a half years, based on its participation in the PortCDM testbeds within the Sea Traffic Management (STM) Validation project, developed a maturity in data sharing. This journey will continue by enhancing port call operations with PortCDM capabilities, as an important milestone in enabling SSS. The PortCDM platform enables real-time situational awareness to all participants involved in the port's maritime activities for the purpose of increasing operational efficiency within and around the port. The scope of this work extends from coordinating port call operations within the port to collaborative decision making across ports. New services for port-to-port collaboration will also be explored and developed.

Port-2-Port (P2P) communication is a lubricant of Short Sea Shipping [31]. Such functionality is of particular importance to the various operators at Limassol. Importantly, since January 2017, following privatization, operations at the Port of Limassol are handled by three private operators: DP World (general cargo and cruise terminal), Eurogate (container terminal) and P&O Maritime (pilotage, towage, and mooring services). The main problem currently identified by all operators is the inability of ships and shipping agents to provide accurate estimates of a ship's intended arrival (ETA). According to Constantinos Aristidou, the berth planner of P&O Maritime: "Normally the shipping agents announce the incoming vessels on the PCS about a week before; however, it sometimes happens that this announcement is made only 8 h before arrival!" This, combined with the short routes between Limassol and the surrounding ports, creates a serious coordination problem for planning the various

operations on the port side to promptly receive a ship (just-in-time) without unnecessary delays. As Constantinos adds: "The distance between the Port of Limassol and some of the closest surrounding ports in the area is about 150 miles (240 km), which means it would only take about 10 h to reach Limassol from those destinations."

4. Quantitative Analysis of Limassol Port Call Data

This quantitative analysis investigates three important factors that can influence port efficiency:

1. The **type of vessel**, which typically determines the berthing location.
2. The **origin of a vessel** (in terms of its port of last departure).
3. The **role of the shipping agent** in managing a vessel's schedule.

The analysis is based on 8070 port calls to the Port of Limassol completed between 1 January 2017 and 13 December 2018. Each port call observation contains ship information (e.g., IMO number, name, type, flag), shipping agent, ports of origin and destination, estimated times of arrival (ETA) and departure (ETD) at/from the traffic area, actual times of arrival (ATA) and departure (ATD) at/from the traffic area, and actual times of berthing (ATB) and unberthing (ATUB). Another 209 port calls were excluded from the analysis due to missing information such as actual time of unberthing or departure. Most of these port calls involved local traffic of smaller vessels (e.g., fishing boats, yachts). No outliers were removed from the dataset as there was no evidence to suggest that any of the data were outliers.

The KPIs used to evaluate port efficiency are defined as follows:

- **Arrival Punctuality** is the percentage of vessels arriving within a period (e.g., 30 min) of the ETA:

$$Arrival\ Punctuality = \frac{Count\ port\ calls\ with\ |ATA - ETA| < 30\ min}{Count\ all\ port\ calls} \times 100 \quad (1)$$

- **Berth Waiting** is the percentage of vessels waiting to berth for some period (e.g., 60 min) after arriving at the port:

$$Berth\ Waiting = \frac{Count\ port\ calls\ with\ |ATB - ATA| < 60\ min}{Count\ all\ port\ calls} \times 100 \quad (2)$$

- **Berth Utilization** for a port call is the percentage of time spent at berth divided by the total time spent in the port:

$$Berth\ Utilization = \frac{ATUB - ATB}{ATD - ATA} \times 100 \quad (3)$$

The selected KPIs are standard in the maritime industry and provide a useful measure of port efficiency based purely on key event timestamps. Please note that arrival punctuality is frequently used in the aviation industry as well. Statistical analysis was carried out using the software package SPSS v17.0 (SPSS, Inc., Chicago, IL, USA). The comparison of averages for each case was based on the analysis of variance (ANOVA) according to Duncan's Multiple Range Test (DMRT) at a 5% significance level ($p \leq 0.05$).

4.1. Effect of Ship Type on Port Efficiency

Ships in the Limassol port calls dataset are grouped into eight (8) main categories based on the classes defined by the United Nations Conference on Trade and Development (UNCTAD) [32]. Table 1 lists the ship types and number of calls for each ship category. For the purposes of our evaluation, we only focus on commercial shipping and, hence, exclude the categories 'Military' and 'Other' from our analysis, which account for about 26% of the total vessel traffic.

Table 1. Ship types and number of port calls per ship category.

Ship Categories	Ship Types per Category	Port Calls	
		Count	Percent
Bulk Carrier	Bulk carriers, combination carriers	802	9.9
Container	Fully cellular container ships	1420	17.6
General Cargo	Multi-purpose and project vessels, roll-on roll-off (ro-ro) cargo, general cargo	1286	15.9
Military	Military ships	477	5.9
Offshore Support	Offshore support/supply vessels	463	5.7
Other	Reefers, tugs, dredgers, other non-cargo ships (yachts, fishing boats)	1630	20.2
Passenger	Cruise, ferries	226	2.8
Tanker	Oil tankers, liquefied petroleum gas carriers, liquefied natural gas carriers, parcel (chemical) tankers, specialized tankers	1766	21.9
Total		8070	100

Figure 4 shows the arrival punctuality per ship category for seven different time periods. Passenger ships exhibit a high arrival punctuality with 61% of them arriving within 30 min of their ETA and an additional 31% within 60 min. This result is expected since passenger ships operate on very strict schedules. There is a statistically significant difference between the arrival punctuality of passenger ships compared to the other categories as determined by a one-way ANOVA ($p < 0.0001$). The arrival punctuality of the other categories is similar and ranges between 41–49% for up to 30-minute difference from ETA.

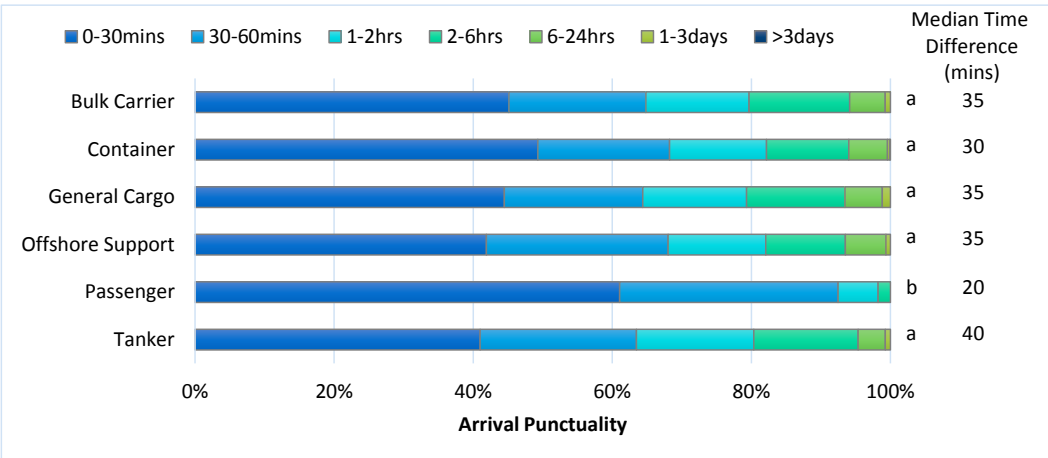

Figure 4. Arrival punctuality and the median time difference between ATA and ETA per ship category. Different alphabet letters between ship categories denote significance at the 5% level using the Duncan Multiple Range Test (DMRT).

Berth waiting, shown in Figure 5, reveals statistically significant difference among almost all ship categories as determined by a one-way ANOVA ($p < 0.0001$). As expected, passenger ships experience the least waiting time with 97% of vessels waiting less than 60 min, while the median waiting time is 23 min (note that this time includes piloting and towing operations). For container and general cargo vessels, berth waiting time (for less than 60 min) drops to around 56%, while for bulk carriers and tankers it is below 30%. Moreover, the median waiting time for bulk carriers and tankers is over 8 and 12 h, respectively. Therefore, a significant fraction of cargo ships spend several hours waiting to berth. It should be noted that some ships may have legitimate reasons for waiting. For example, tankers and

offshore support vessels might spend time in the anchorage area refueling or servicing other ships rather than waiting for a berth. Further data collection is required for such vessels to compute their actual waiting time.

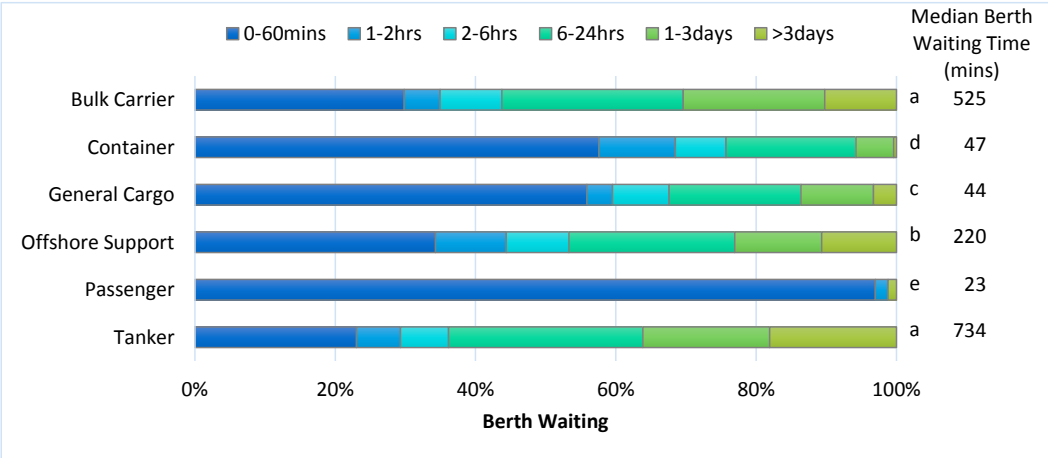

Figure 5. Berth waiting and median time difference between ATA and ATB per ship category. Different alphabet letters between ship categories denote significance at the 5% level using the DMRT.

Berth utilization, shown in Figure 6, exhibits similar patterns to berth waiting, with statistically significant differences among all ship categories as determined by a one-way ANOVA ($p < 0.0001$). Once again, passenger ships exhibit high berth utilization (95%) as they typically proceed to berthing without delays and remain there until their departure. Container, general cargo, and bulk carrier vessels have 92%, 88%, and 83% median berth utilization, respectively. Even though bulk carriers exhibit much higher berth waiting times, they spend considerably more time at berth (median time = 52 h) compared to container and general cargo (median time = 18 h), which increases their berth utilization metric. Tankers and offshore support vessels can spend a lot of time outside the port providing refueling and other services, which naturally contributes to a lower measure of berth utilization, as currently defined.

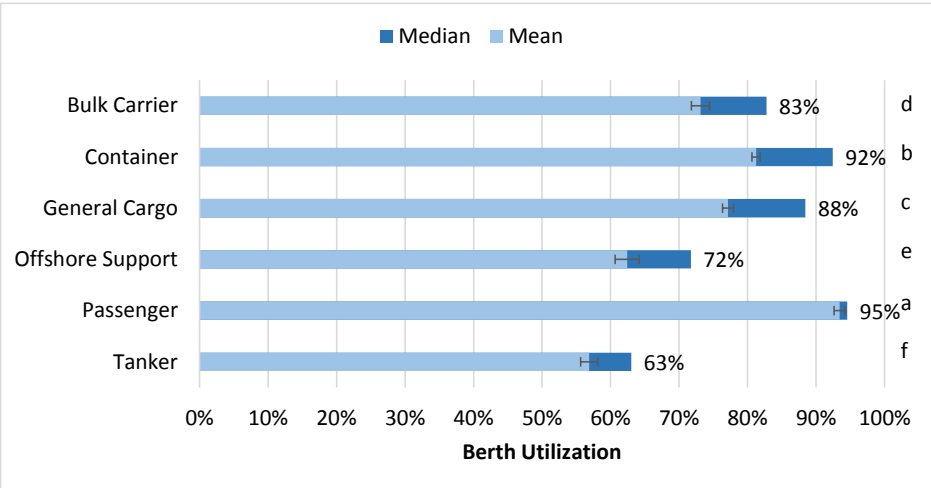

Figure 6. Mean and median berth utilization per ship category. Different alphabet letters between ship categories denote significance at the 5% level using the DMRT.

4.2. *Effect of Vessel Origin on Port Efficiency*

The Port of Limassol receives vessel traffic from 448 ports in 66 countries. To support interpretation of our analysis, we group all referenced countries into ten (10) regions, listed in Table 2. The East

Mediterranean region accounts for 57.9% of the total traffic to the Port of Limassol, while 17.3% comes from other ports in Cyprus. The West Mediterranean and Black Sea regions contribute 11.3% and 9.6%, respectively, while the remaining regions account for 3.9%.

Table 2. Countries and number of port calls by a vessel's region of origin.

Region	Countries	Port Calls	
		Count	Percent
Africa	Congo, Côte d'Ivoire, Kenya, Morocco, Mauritania, Nigeria, Senegal, Tanzania	5	0.1
Arabian	Arab Emirates, Djibouti, Iraq, Oman, Qatar, Saudi Arabia, Sudan, Yemen	33	0.5
Asia	Bangladesh, China, India, Sri Lanka, Malaysia, Singapore, Turkmenistan	36	0.6
Black Sea	Bulgaria, Georgia, Moldova, Romania, Russia, Turkey, Ukraine	620	9.6
East Med	Egypt, Greece, Israel, Jordan, Lebanon, Syria	3740	57.9
Local	Cyprus	1117	17.3
N. America	Bahamas, Mexico, United States	12	0.2
N. Europe	Belgium, Germany, Denmark, Great Britain, Ireland, Netherlands, Norway, Poland, Sweden	144	2.2
S. America	Argentina, Brazil, Curacao, Trinidad	18	0.3
West Med	Albania, Algeria, Spain, France, Gibraltar, Croatia, Italy, Libya, Montenegro, Malta, Portugal, Slovenia, Tunisia	729	11.3
Total		8070	100

Figure 7 shows ship arrival punctuality by those regions of origin with more than 35 port calls. There is a statistically significant difference between origin regions as determined by a one-way ANOVA ($p = 0.007$) and shown in Figure 7. Ships arriving from N. Europe and Asia exhibit high arrival punctuality (61% and 58% arrive within 30 min, respectively) and a relatively low median time difference between ATA and ETA (about 21–22 min). On the other hand, ships arriving from the Black Sea area have the lowest arrival punctuality at 37% and a more than double median time difference of 45 min.

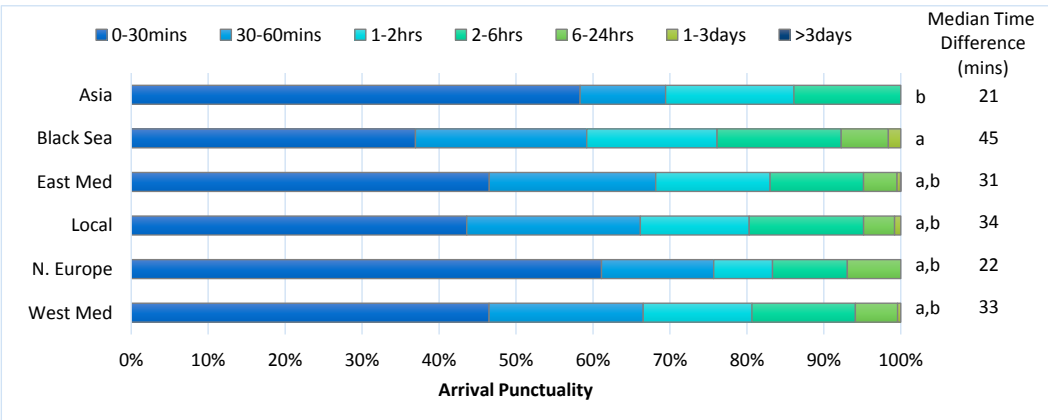

Figure 7. Arrival punctuality and median time difference between ATA and ETA by a vessel's region of origin. Different alphabet letters between ship origin regions denote significance at the 5% level using the DMRT.

Berth waiting statistics reveal differences based on vessel's region of origin, as identified by a one-way ANOVA with a statistically significant difference ($p < 0.0001$), as shown in Figure 8. Ships arriving from Black Sea and Asia suffer the longest waits with only 11% and 15%, respectively,

berthing within 60 min of arrival at the port area. In fact, their median berth waiting is over 23 h for both, and this is clearly an area that requires further analysis to determine the cause. On the other hand, 53% of ships originating from East or West Mediterranean experience less than 60 min berth waiting, while that percentage is as high as 70% for ships from N. Europe (with a median berth waiting time of only 39 min).

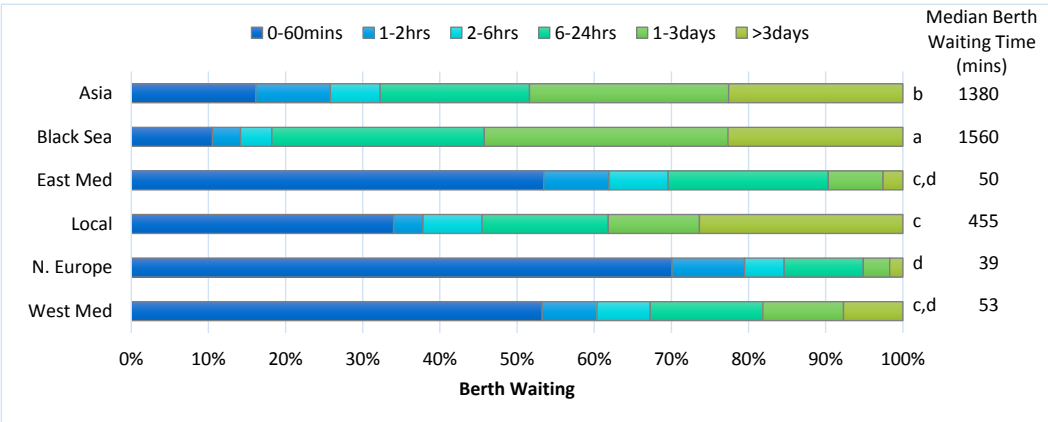

Figure 8. Berth waiting and median time difference between ATA and ATB by regions of origin. Different alphabet letters between ship origin regions denote significance at the 5% level using the DMRT.

4.3. Effect of Shipping Agents on Port Efficiency

The 8070 port calls were managed by 92 different shipping agents, whose frequency distribution of ships handled is shown in Figure 9. About half of the shipping agents managed less than 20 ports calls each during the two years of data comprising our dataset, while 9 of them handled about half of the traffic at the Port of Limassol. For our analysis, we focus on the top 27 agents, who managed more than 100 port calls each and account for 86% of the total traffic.

To assess the effect that the shipping agent has on the shipping process, we computed vessel arrival punctuality (within 0–30 min) and berth waiting (between 0–60 min) for the top 27 agents, shown in Figure 10. We observe significant variations for both metrics: arrival punctuality varies between 29% and 92% with statistically significant differences determined by a one-way ANOVA ($p < 0.0001$), while berth waiting time varies between 3% and 93% with also statistically significant differences determined by a one-way ANOVA ($p < 0.0001$). Please note that the underlying data show no correlation between the two KPIs ($corr = -0.00074$). Based on the observed data, some agents (e.g., Agents 15 and 16) are highly effective in ensuring that their ships arrive just in time at the port and are berthed with minimal delays, while others (e.g., Agents 3 and 23) exhibit the exact opposite behavior. Another interesting observation is that several agents (e.g., Agents 9 and 17) achieve a relatively high arrival punctuality (of over 50%), yet only a small fraction of their ships are berthed without delays. Finally, even though some agents (e.g., Agents 1 and 10) suffer from low arrival punctuality (<34%), they can achieve low berth waiting times. Overall, our analysis reveals that there is considerable variation in the performance of shipping agents based on the two KPIs examined. This supports our introductory contention that a port is a socio-technical system and that social factors can impinge port efficiency.

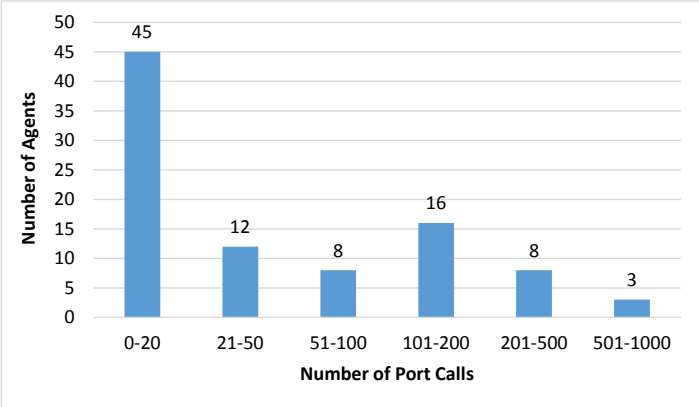

Figure 9. Histogram of the number of agents managing port calls at the Port of Limassol.

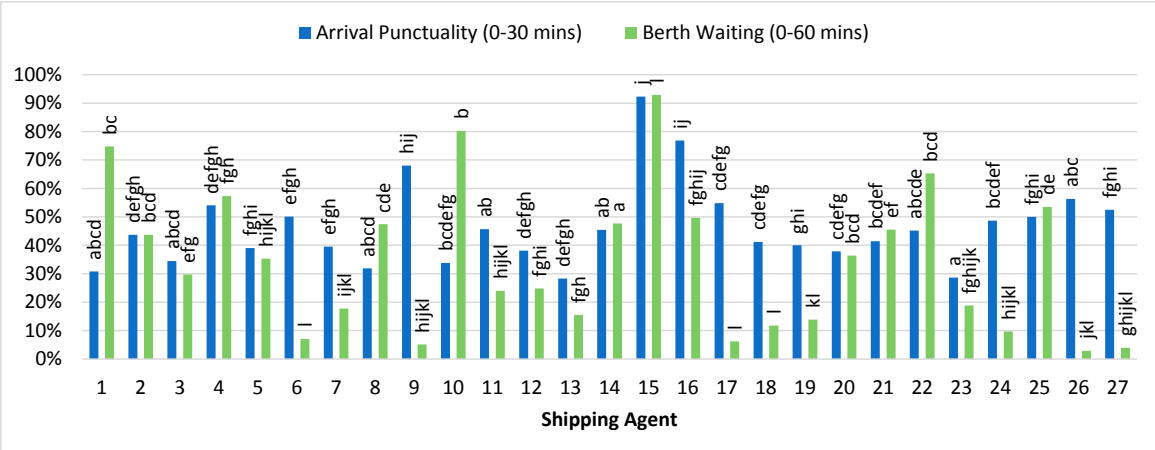

Figure 10. Arrival punctuality (within 0–30 min) and berth waiting (between 0–60 min) by shipping agent. Different alphabet letters between shipping agents denote significance at the 5% level using the DMRT. The DMRT analysis was performed separately for each KPI.

4.4. Effect of Multiple Factors on Port Efficiency

To further dissect the effect of the three main factors (namely, ship type, vessel origin, and shipping agent) on port efficiency, we also performed all pair-wise analyses and observed interesting variations for all pairs.

Ship type by vessel's region of origin: A statistically significant interaction exists for arrival punctuality between ship types and vessel's region of origin based on a two-way ANOVA ($p < 0.0001$), as shown in Figure 11. We present the results for the three most important ship categories (i.e., Container, General Cargo, Tanker) that together account for more than 55% of the ship traffic to the Port of Limassol. We observe that the origin region has a different effect on arrival punctuality for each of the three ship categories. In particular, tankers arriving from Asia have a significantly higher arrival punctuality (68%) compared to tankers arriving from the other regions and the overall average arrival punctuality of 41% ($p = 0.0023$). For the General Cargo category, ships from N. Europe lead with an arrival punctuality of 72%, which is significantly higher than the average of 44% ($p < 0.0001$). On the other hand, there is no statistically significant difference ($p = 0.251$) among origin regions for Container ships.

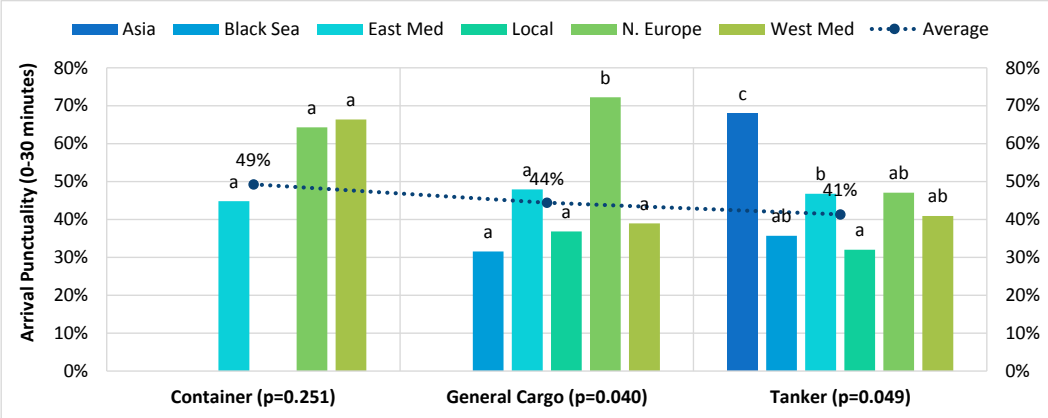

Figure 11. Arrival punctuality (within 0–30 min) by ship type for each region of origin (with >10 port calls). Different alphabet letters between regions of origin denote significance at the 5% level using the DMRT for each ship type.

Ship type by shipping agents: Two-way ANOVA reveals a statistically significant difference ($p < 0.0001$) for arrival punctualities between ship type and shipping agent. Figure 12 shows arrival punctuality (within 0–30 min) for the three main ship categories and the top 27 shipping agents. For each ship category, we observed statistically significant variations among the shipping agents ($p < 0.0001$ in all cases), ranging from 25% to 77% of arrival punctuality, while the average lies between 41% and 49%. Some shipping agents appear able to ensure that most of their ships arrive at the port as scheduled, while others have major difficulty in planning arrivals. It is interesting to note that most shipping agents manage only one category of ships, and hence appear only once in Figure 12.

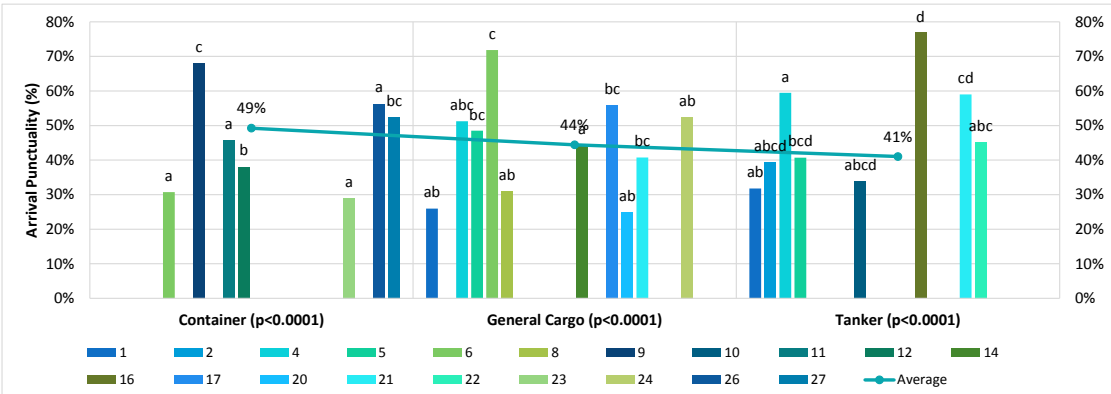

Figure 12. Arrival punctuality (within 0–30 min) by shipping agent for each ship type (with >10 port calls). Different alphabet letters between shipping agents denote significance at the 5% level using the DMRT for each ship type.

Vessel's region of origin by shipping agents: The analysis of arrival punctuality in terms of vessel's region of origin and shipping agents also reveals statistical significant differences, as determined by a two-way ANOVA ($p < 0.0001$). Figure 13 shows the arrival punctuality for each shipping agent for the East and West Mediterranean regions, which account for almost 70% of the total traffic at the Port of Limassol. Once again, the role of the shipping agent is decisive with some achieving over 70% of arrival punctuality (within 30 min) while others score below 30%. These results are similar for the other regions of origin as well, showcasing that the shipping agents strongly influence a ship's arrival punctuality.

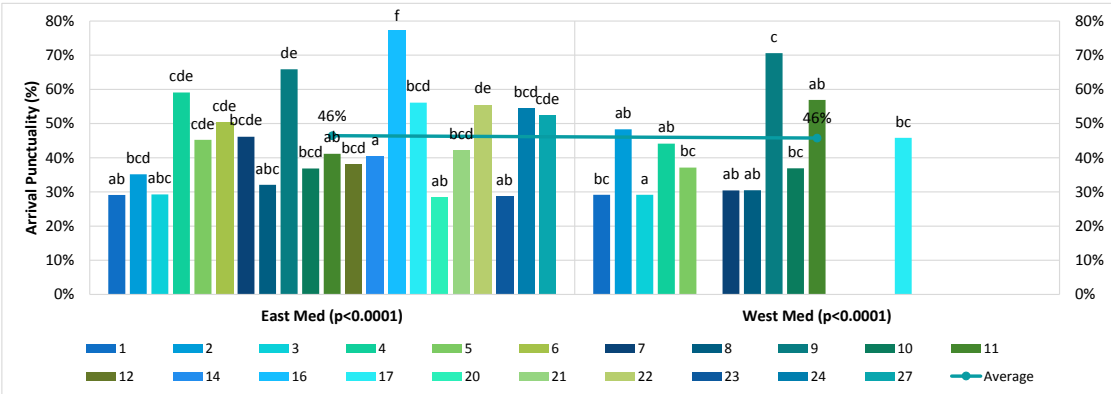

Figure 13. Arrival punctuality (within 0–30 min) by shipping agent for each region of origin (with >10 port calls). Different alphabet letters between shipping agents denote significance at the 5% level using the DMRT for each origin region.

5. Discussion

In this article, we report some of the main identified challenges for advancing reliability, quality, and safety as well as removing unnecessary costs and delays at SSS hubs, with a particular focus on Cyprus and the Eastern Mediterranean.

5.1. Successful Operations Require Planning

Port operators need a sound framework and accurate data for planning their operations. To realize a port call that meets expectations, such as fast turnaround, just-in-time operations, and minimal waiting times for all involved, port operators need to ensure that all involved parties have access to the necessary data for their planning in a timely fashion. This includes both data related to a port's internal capabilities, such as the availability of resources and infrastructure required to serve a ship, as well as data on external conditions, such as the progress of a ship travelling towards a specific port. This means, for example, the ability to forecast with high precision the time of departure of a ship from a specific berth location, especially when another ship is planning to use the same berth in the near future. The same goes for ship movements in that a port should be able to forecast with high precision the ETA of a particular ship to its service area.

The weakest link in a port call's chain of operations often determines its success. Therefore, all actions associated with a port call need to be considered. For example, a port may have streamlined coordination of all its internal operators (pilots, tug-boats, linesmen, terminals), but a wrong estimate of the time of arrival can easily disrupt the entire process. Consider, for example a hypothetical scenario where a ship is scheduled to depart from Haifa at 8 pm and arrive the next day to Limassol at 4 am. The ETA was properly entered into the Port Community System (PCS) of Limassol by the corresponding shipping agent one week in advance. Now, due to unforeseen problems (e.g., bad weather, crane malfunction, or strike) at Haifa, the ship is unable to depart at the scheduled time. However, nobody notifies Limassol of this change. As a result, at 4 am the next day when Limassol is expecting to receive the ship, it is still in Haifa. Note that this situation, of making unnecessary preparations at the Port of Limassol to receive the ship, could have been easily avoided if the ports of Haifa and Limassol were able to communicate with each other about ships that steam between the two ports. According to Constantinos Aristidou (P&O Maritime, Berth Planner): "Port-2-port communication can really help in improving the predictability of the vessel arrival time at the Port of Limassol, especially in situations of unforeseen delays at the previous port like bad weather or strikes."

The importance of P2P communication in providing timely and valid information to the ship owners is also highlighted by Captain Stelios Colombos, currently a VTS operator in the Port of Limassol. To the question of whether P2P communication can help, Stelios reply was: "In my opinion, of course. The ultimate purpose of the entire system is to provide ship owners with timely and valid

information about the foreseeable status of the ports so they can plan where to load and unload their ships." The cost of bad planning for ship owners is also highlighted in the following example provided by Captain Stelios: "For example, consider a ship which is in the Port of Alexandria and is expected to be unloaded on 10-03-18 at 12.00 local time, and is expected the following day at the Port of Limassol. The ship's agent will make arrangements for the arrival of the ship, that is to say, tugs, pilot, mooring men, which entails a large cost to the ship-owner. Suppose now, there will be a delay in the ship's departure from the Port of Alexandria either due to weather or asymmetric situations without the shipping agent being informed at Limassol about this delay. The cost to the ship-owner will be enormous!" Captain Colombos provides an important dimension for the need for P2P communication, that of saving money for the ship owners. In his own words: "That is why I am convinced that communication between ports is imperative for valid, timely, information of all those involved in the management of the ship in order to avoid unnecessary expenses that will result in financial suffocation and strangulation of ship owners and possibly large job losses in the maritime sector."

As the preceding discussion highlights, shipping agents play a critical role in determining a port's operational efficiency. Furthermore, the preceding analysis of agent performance shows wide variation. This finding surprised us and was a byproduct of our initial analysis focusing on variations due to ship type and port of departure. Thus, we now recognize that there is a need for further research than examines the work of agents, how they make decisions and what information systems could improve these, and how they interact with ship owners and port facilities managers both in terms of communication channels and data sharing. We need to learn more about the social system that we now know in order to directly impact port efficiency.

The lack of P2P facilities and other information sharing capabilities handicaps agent performance and limits the gains from technological innovations. A smoothly operating social system lubricates the technical system, resulting in higher levels of efficiency and sustainability. This social system can be improved by data sharing, such as that proposed by PortCDM.

5.2. PortCDM for Increased Efficiency in Short Sea Shipping

To both manage and avoid unforeseen disruptions, STM introduced PortCDM [33,34] for expanding the planning horizons of port call processes, and the alignment of all actors in port call operations. Coordination is based on standardized data sharing that reflects the spatial and temporal nature of a port call. These shared data can also constitute a valuable system of records for efficiency analysis and port planning.

PortCDM builds upon the idea that the timing of intentions and time when actions are completed are shared via a standardized message format on time stamps. Each message has a timestamp, such as when an event is planned, and the required resources and location, as appropriate. These data are used for planning the systems of production within a port, such as container handling. They are also captured as a system of record for port performance analysis and resource planning. The shared data should cover all the different dimensions of the port call process, from a ship's intended arrival at the port area until it leaves after having been served according to the purpose of call.

For the port call process to be realized as efficiently as possible, all involved actors need to be aligned in their operations and thereby, integrated performance throughout the port call process is highly likely to be achieved. By capturing shared data, such as agreements of operations, planned ship movements, outcomes of service deliveries and movements, the involved actors can gain insights into the consecutive progress of a ship's port call and provide a basis for planning. PortCDM promotes real-time data sharing as a means of providing all involved actors a common situational awareness. This enables them to adjust their plans accordingly and to make updates independently as they occur before or during a port visit.

SSS is particularly challenging because of the short horizon for the planning of operations. PortCDM can assist by supporting the exchange of standardized messages between neighboring ports.

As identified within the STM validation project, there is a desire for the downstream port to know the progress in the current port visit and to know the status of subsequent ports in a sequence of port visits. Special focus is directed towards the provision of data of the estimated and actual time of departure from the previous port (ETD and ATD) and the ETA to the next port. These data when accurately communicated between ports can form the basis for better coordination of the port call activities at the port of destination, especially when there is only a short distance between the visited ports. Equally important, of course under SSS conditions is to continually track the vessel at sea, either by continuous ship-2-port communication or by other means of tracking, once the voyage begins. Ship-2-port communication within STM is enabled through the exchanging of voyage plans in a standardized format between the ship and the destination port. We emphasize that the various decisions made at the upstream port (e.g., slowing down port operations due to insights of what is happening in the next port) are data elements for establishing situational awareness for everyone, including the destination port, the captain of the ship, and the shipping company. The ship captain, ultimately, is the one who decides when to leave berth and other such ship-oriented decisions.

For PortCDM to be a reality, ports and ships must be able to communicate by digital means in a common language and format. P2P communication is enabled by the Port Call Message Format (PCMF), forthcoming as a S-211 standard [35]. Facilitated by PortCDM the ultimate objective is to ensure high reliability and accuracy of data for all involved actors based on a shared and common situational awareness. This can be achieved by adopting principles for ensuring a high degree of predictability, such as the combination of multiple data sources providing event timing data in real time and aligned actors with each other in terms of shared data and situational awareness.

5.3. Benefits of Enhanced Port-2-Port Collaboration

PortCDM is expected to have a lasting impact on the maritime sector at both the national and international level. Towards this end, the ports of Cyprus, and especially the Port of Limassol will be upgraded as information hubs, exchanging information with both nearby ports and ships in the Eastern Mediterranean. Such enhancement will upgrade the capabilities of all port actors involved in the port call process including the shipping agents. Moreover, the P2P communication can help establish the Cyprus ports as transshipment hubs for SSS by improving their competitiveness in the area. Of course, a successful transshipment hub needs a complementary combination of efficient cargo handling equipment and digital data sharing to ensure the maximum use of investments in the hub and to enhance the value of shipping in its catchment area. This is expected to increase the maritime traffic in the Eastern Mediterranean and especially through the Cyprus ports, thus stimulating economic growth of the maritime sector in Cyprus. The proposed solutions will help enhance the political and economic position of Cyprus in the Eastern Mediterranean and will improve communication with other nearby countries and ports, such as Damietta and Alexandria in Egypt, Haifa and Port Said in Israel, and Aqaba in Jordan. Therefore, P2P communication can contribute to the creation of an appropriate environment for the reduction of goods' transport fees, to and from the aforementioned countries. The wider upgrading and optimization of the port services is expected to have a positive impact on the cost of transporting Cypriot freight, resulting in positive effects for Cypriot traders and consumers. The enhanced SSS operations can help towards upgrading the maritime significance of Cyprus, not just in the Eastern Mediterranean area, but globally.

6. Conclusions

As the data analysis clearly reveals, there is considerable variation in shipping agent performance regarding planning the arrival and berthing of a ship in Limassol. Poor performing agents reduce port efficiency because their low-quality estimates disrupt orderly planning. They also have an environmental impact because a waiting ship is like a car in a traffic jam; it is burning fuel but going nowhere. Furthermore, efficient planning leads to higher use of existing resources, which is an ecological gain. We propose several actions to improve an agent's performance, and consequently

a port's efficiency and the sustainability of SSS. Shipping agents can be agents of change for sustainable shipping.

First, the port should publish regularly, say monthly, the two KPIs, and maybe others, used in this study for each shipping agent. Shipping companies and port operators need agent performance transparency so they can pressure the poor performers to do better or shift their business to high performers. Agents and ship owners participate in a market where the ship owners buy services sold by agents. Efficient markets need to be information rich to provide all buyers and sellers the wherewithal to make smart self-interest motivated decisions. The wide variation of agent performance suggests that the Limassol ship-agent market is inefficient. Efficient markets create uniformly high outcomes because those who cannot meet buyers' expectations are driven out of business.

Second, to help shipping agents ramp up their skills, Limassol should invest in the continuous improvement of the social system, as well as the technical system. This means ensuring all agents learn how port-2-port communication can be used to improve their performance, understand the principles of PortCDM, and learn how to interact effectively with shipping companies. Similarly, ship owners and captains, particularly those who visit frequently, should have the opportunity to learn how to interact effectively with the port. Many successful companies 'train' their customers to make their interactions with the company more efficient for both parties. We see this in action when we order fast food, board a plane, and order online. Furthermore, to ensure a high level of goodwill within the port's social system, we recommend that the continuous improvement program starts soon and in advance of the first recommendation related to agent performance transparency, because agents should be first given a chance for self-improvement.

Third, all changes in the technical system should be evaluated in terms of their impact on the social system and how synergistic change across the entire socio-technical system of the port can be executed to raise the joint performance of both. As well, such changes in both systems should be accompanied by the broadcasting of transparent KPIs that allow the shipping agent and other port-related markets to also raise their efficiency. A limitation of this study is the absence of event data for when a vessel enters the traffic area, berths, commences cargo operations, and departs. We plan to collect these additional data in order to properly quantify the various inefficiencies associated with delays and idle times. PortCDM is a suitable platform for facilitating the necessary data sharing.

Increased SSS is an opportunity to lower the ecological footprint of goods and passenger transportation, but its proponents need to recognize that there is a market for the movement of goods and services. In this market, the winners offer high reliability at a competitive price. The wide variation of shipping agent performance of Limassol is an unnecessary friction retarding higher rates of SSS in the Eastern Mediterranean. We propose applying the lubricant of information transparency empowered by concepts such as PortCDM to eliminate this friction.

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Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

ATA	Actual Time of Arrival
ATB	Actual Time of Berthing
ATD	Actual Time of Departure
ATUB	Actual Time of Unberthing
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
IMO	International Maritime Organization
KPI	Key Performance Indicator
MoS	Motorways of the Sea
P2P	Port-to-Port
PCS	Port Community System
PortCDM	Port Collaborative Decision Making
SSS	Short Sea Shipping
UNCTAD	United Nations Conference on Trade and Development

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