Multidisciplinary
SCIENTIFIC JOURNAL
OF MARITIME RESEARCH

University of Rijeka
FACULTY OF MARITIME STUDIES

Multidisciplinarni
znanstveni časopis
POMORSTVO

https://doi.org/10.31217/p.36.2.22

Schedule Reliability in Liner Shipping: A Study on Global Shipping Lines

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ABSTRACT

Due to the complex structure of the transportation systems, disruptions in transport operations may occur from time to time. In liner shipping, it is seen that shipping lines frequently deviate from the transit times announced in their vessel schedules, and this leads to schedule unreliability. This leads to schedule unreliability and affects all stakeholders. Based on actual transportation data, this study aims to evaluate the transit time reliability performance of shipping lines and the factors that may affect transit time reliability to investigate schedule reliability in liner shipping. To evaluate the transit time reliability of shipping lines', transit time deviations were calculated based on observations containing 5080 transport data of shipping lines and current performances are discussed. Hypotheses were tested with independent sample t-test and Welch's ANOVA to examine the factors affecting transit time reliability. Tamhane's T2 post-hoc test was used to determine the difference between groups. Results show that transit time reliability of shipping lines is low. It has been observed that the type of service, season, vessel age, and TEU capacity of the vessel factors affect the transit time reliabillity. With this study, shipping lines can evaluate their reliability performances according to the competition. At the same time, lines can use these results to understand, evaluate and manage factors that affect their transit time reliability. In this direction, suggestions have been made to the shipping lines to contribute to improving transit time reliability and service quality. This article is regarded to close the gap in evaluating transit time reliability in liner transportation because it relies on actual transportation data.

ARTICLE INFO

Preliminary communication
Received 8 November 2022
Accepted 22 December 2022

Key words:
Liner shipping
Transit time reliability
Transit time deviation
Schedule reliability
Container shipping lines
Transportation

1 Introduction

Good management of time in ship operations is becoming increasingly important (Salleh et al., 2017). In liner shipping, transportation activities are carried out between predetermined fixed routes, and vessels call at more than one port within a specific route and program. Due to the nature of maritime transportation and ports, uncertainties may occur at many stages of transportation, potentially disrupting vessel schedules. Many factors affect the transit time (the time it takes for a container to be transported between two ports) (Stefan and Leena, 2013). Transit time reliability measures how often shipping lines adhere to transit times specified in the advertised programs.

In the liner shipping ecosystem, many individuals and organizations contribute to the system with different tasks and affect the system's structure. Those contributing to the liner shipping ecosystem include ship owners, shipping agents, forwarders (transportation brokers), ship supply companies, container port operators, shippers, class and insurance companies, stevedoring companies, customs administration, maritime police, banks, and others (Tuna, 1999). The problem of transit time reliability affects all parties from different aspects throughout the supply chain. This situation makes it impossible for parties to plan correctly and stay faithful to these plans (Mongelluzzoe, 2018).

Shipping delays began accumulating in late 2020 and worsened in early 2021. They clogged inventory for weeks while ships waited for berths, and offloaded containers had to wait for long periods at overcrowded freight ports. Shipping managers noted that the most significant delays were are in the ports of Los Angeles and Long Beach (Costas, 2021). Especially low schedule reliability combined with the import boom in the US before Christmas resulted in many ships waiting at the ports to berth and continued to reduce program reliability. Likewise, European shippers have difficulty receiving their imports on time (Angell, 2021b). Cargo delivery delays have occurred at various locations, including docks, railroads, truck terminals, and distribution centers, generating supply shortages and forcing everyone to pay several times more for transportation than the prior year (Costas, 2021). A major issue affecting shippers is rescheduling domestic transportation at the last minute due to late or early arrival (The Load Star, 2020). It is stated that poor schedule reliability combined with high consumer demand poses numerous challenges to shippers and forwarders. Because of these delays, many shippers are looking for alternative options, such as air transport and less than container load (LCL) ocean transport (Salgado, 2021). Besides, because of these supply-side problems, freight rates remain at or near record levels (Lademan, 2021).

Low schedule reliability can be caused by several factors, many of which are beyond the control of shipping lines. Also, the COVID-19 pandemic affected the sector and influenced the growth of the problem. Port closures owing to COVID-19 outbreaks, such as the port of Yantian in May and the port of Ningbo in August, have exacerbated the situation. As a result, numerous vessels were redirected to avoid these port calls, resulting in long lines in ports worldwide (Griffiths, 2021). The primary US trade gateway has been strangled by intense demand from US importers to replenish stocks depleted during last year's COVID-19 limitations, resulting in massive ship jams offshore (Costas, 2021). Schedule and transit time reliability problems increase supply chain costs and have severe consequences for various actors in the supply chain (Vernimmen, Dullaert and Engelen, 2007). For example, it causes a decrease in efficiency for the shipping lines and the need to reprogram the vessels, which returns as additional operating costs (Notteboom, 2006). The problem also affects terminal operators. The vessel, which cannot dock at the previously planned dock area due to its delayed arrival, affects all the planning in the terminal (Vernimmen, Dullaert and Engelen, 2007). From the consignor/consignee side, the costs arising from shipping delays may be attributed to additional holding costs, additional labor costs, losses due to the depletion of stocks, or the risk of losing customers/business (Mckinnon, 1998).

Vernimmen, Dullaert, and Engelen (2007) focused on the effect of program reliability on manufacturers' inventory holding levels. These authors concluded that improving program reliability would lead to significant cost savings for manufacturing enterprises by reducing the current safety stock level. Inbound and outbound logistics activities are also affected by transit time reliability. Because of the delays, disruptions may occur in production, and therefore, this may cause lost revenues and extra costs. From the point of view of outbound logistics, being unable to reach the customer at the desired time can cause problems, such as collection problems, additional costs, and loss of customers. Logistics companies engaged in domestic transportation are also affected by the program/transit time reliability problem experienced in liner transportation. The work efficiency of these enterprises, which plan according to the planned schedule of the vessels, is significantly reduced when they are faced with increasing delays (Vernimmen, Dullaert, and Engelen, 2007).

Global shipping line operators, which enable cargo transportation between ports along many different trade routes, have approximately 500 liner shipping services scheduled weekly (Prokopowicz and Berg-Andreassen, 2016). It is difficult for shipping lines to provide transit time reliability due to the liner shipping network's complexity, the transport system's structure, and the diversity of parties involved.

Sea Intelligence is a research and analysis provider in maritime container transport. Sea Intelligence regularly conducts research and publishes data on the schedule and transit time reliability of shipping lines. The recently published Global Liner Performance 125 report covers data from 34 different trade lines and more than 60 shipping lines. According to the report, shipping lines' global schedule reliability was 32.0% in December 2021, an all-time low for the 10 years the organization has analyzed global schedule reliability. Only nearly one-third of the vessels comply with the transit times specified in the vessel schedules (Angell, 2021a; Sea Intelligence, 2022). Studies show that transit time reliability in global liner shipping is low. And reliability values vary among trade routes and shipping lines (Vernimmen, Dullaert and Engelen, 2007).

In liner shipping, providing punctual service by adhering to the preplanned estimated transit times in the schedules of container vessels is one of the essential factors in service quality (Abioye et al., 2020). When selecting shipping lines, transit time is an increasingly important factor (Fanam and Ackerly, 2019). Transit time and transit time reliability in liner shipping vary considerably between lines. Differences in transit time performance significantly impact shippers' carrier selection decisions (Saldanha, Russell, and Tyworth, 2006: 52). A study has shown that transit time and reliability are among the top three equally important criteria for shippers in choosing ocean carriers, forcing container line operators to prioritize these parameters (Armbruster, 2002).

Schedule and transit time reliability studies typically address public transport, passenger transport, and road transport. A few maritime transport studies have focused on program recovery and optimization. Gaonkar et al., (2011) and Nair and Mason (2012) analyzed the scope and decisive factors of schedule reliability. Wang, Li and Wu (2010), Song, Li and Drake (2015), and Zhang, Zheng and Teo (2020) proposed optimization models for schedule reliability. Allen, Mahmoud, and McNeil (1985), Notteboom (2006), Zhang and Lam (2014), and Vernimmen, Dullaert, and Engelen (2007) analyzed the impacts of transit time and schedule reliability on different actors. Notteboom (2006) and Chung and Chiang (2011) examined the factors influencing transit time and schedule reliability. Brouer et al. (2013), and Abioye et al. (2020) developed models addressing the vessel schedule recovery problem. Lee, Lee and Zhang (2015) studied the effects of slow steaming on schedule reliability. Saldanha, Russell and Tyworth (2006) analyzed the speed and transit time performance of shipping lines. Wu, Deng and Tian (2009), Fancello et al. (2011), and Salleh et al. (2017) developed a calculation model for vessel delays, punctuality, and transit time reliability.

2 Literature Review

In liner shipping, studies have generally been carried out on the choice of carrier and cost minimization. Studies on program reliability in maritime transport commonly focus on network design, vessel schedule recovery, and optimization. Only a few studies have focused on transit time reliability and the factors influencing it.

Gaonkar et al., (2011) and Nair and Mason (2012) conducted studies to reveal the extent and determinants of transit time and schedule reliability. Goankar et al. (2011) have modeled decisive factors that can be used to assess the operational reliability of maritime transportation systems. The operational reliability analyzed in the study covers the criteria: intended mission completion, timeliness, and safe mission. First, they identified factors that directly affect the reliability of maritime transportation. These factors are congestion at the source harbor, congestion at sea, congestion at the destination harbor, weather or environmental conditions, age of the ship, technological up-gradation of the ship, experience of the operational or navigation crew, the experience of maintenance workforce, effectiveness of maintenance programs, the effectiveness of the emergency system on the ship, unforeseen events, and overall past operational history of the ship. Among these factors, they correlated congestion at the source harbor, congestion at sea, and congestion at the destination harbor with timeliness. Other factors were correlated with the safe mission and intended mission completion. Nair and Mason (2012) identified three determinants of schedule reliability: the demand perspective of shippers, the supply-side perspective of providers, and the liner services framework. They suggested that these three decisive factors should be considered in the design of future studies.

Several attempts have been made to analyze transit time and schedule reliability by developing an optimization model (Wang, Li and Wu 2010; Zhang, Zheng and Teo 2020; Song, Li, and Drake (2015). Wang, Li and Wu (2010) have addressed the schedule reliability problem regarding the berth planning and allocation process in container terminals and proposed an optimization model for the schedule reliability problem. Their research focused on the minimum average scheduled missed hours of vessels between the scheduled departure time and the actual departure time, and they concluded that their model reduces average scheduled missed hours by 40 %. Song, Li, and Drake (2015) have developed a stochastic multi-objective optimization model to optimize the expected cost, service reliability, and shipping emissions under uncertain port time conditions. Zhang, Zheng, and Teo (2020) formulated a stochastic optimization model to combine program reliability objectives in ship program design and considered fuel consumption, voyage time, and program delays. The model was validated using data from the Daily Maersk service. The authors' model provided higher program reliability than Daily Maersk.

Data from the research organization Sea Intelligence show that only one-third of the ships provide reliable service (Sea Intelligence, 2022). Providing services with low schedule reliability in liner shipping affects the actors along the supply chain in various ways. Allen, Mahmoud, and McNeil (1985), Notteboom (2006), Vernimmen, Dullaert and Engelen (2007), and Zhang and Lam (2014) investigated the impacts of transit time and schedule reliability on different actors in the system. Allen, Mahmoud, and McNeil (1985) focused on the impact of transit time reliability on shippers, receivers, and carriers. These authors proposed a model demonstrating how a shipper wishing to minimize cost could adjust the economic order quantity according to transit times or reliability changes. Notteboom (2006) has discussed the shipping lines' prevention and planning tools for managing time factor in liner shipping service design and maximizing schedule reliability. Vernimmen, Dullaert and Engelen (2007) investigated the impact of reduced program reliability and integrity on shippers and consignees, one of the actors in the system. Zhang and Lam (2014) have measured the impact of the Daily Maersk service, which operates daily instead of weekly services and was started by Maersk to improve schedule reliability and service frequency in the liner shipping and port industry. They reported that the service has significantly reduced supply chain stocks, including safety stock. Although it achieved 95 % on-time cargo delivery with Daily Maersk, the service was canceled in 2015 because customers were unwilling to pay a higher price for better service (Porter, 2015).

Various problems, such as adverse weather and unexpected port conditions, contribute to maritime transport disruptions. Disruptions at the ports of call and at sea affect the planned vessel schedules and cause monetary losses and various negative situations for shipping lines. In this case, an effective vessel schedule recovery plan is crucial. For such purposes, Brouer et al. (2013) and Abioye et al. (2020) have developed a model for the Vessel Schedule Recovery Problem (VSRP).

When the vessels move at low speeds during the voyage, less fuel is consumed, and fuel savings are achieved. For such reasons, vessel speeds are sometimes reduced, which is called slow steaming. However, this may result in increased transit times. Lee, Lee and Zhang (2015) developed a model to examine the relationship between shipping time, bunker cost, and delivery reliability. The researchers suggested that a controlled balance can be struck between guaranteed delivery reliability and cost. Saldanha, Russell and Tyworth (2006) have analyzed the speed and reliability of ships in liner shipping and state that the transit time performances of shipping lines differ in specific trade routes. Findings also demonstrate that the season affects the transit times and reliability of shipping lines' services.

Several studies have been conducted to calculate ship punctuality, delays, and time reliability. Wu, Deng and Tian (2009) have developed a computational model for the time reliability of the liner shipping network using the simulation method. The problem of transit time reliability significantly affects and complicates the planning and management of port operations and all parties in the maritime transportation ecosystem. For this purpose, Fancello et al. (2011) have proposed two algorithms to estimate vessel delays. Salleh et al. (2017) have presented a model to calculate the arrival punctuality of vessels using the Fuzzy Rule-Based Bayesian Network method.

Only a few studies have comprehensively addressed the factors that cause transit time and schedule unreliability, such as Notteboom (2006) and Chung and Chiang (2011). And in these studies, data were obtained through questionnaires. Notteboom (2006) assessed the causes of schedule unreliability and reported that most sources of schedule unreliability on the East Asia-Europe route are related to port/terminal conditions. The reasons for vessel delays are also categorized as follows: port/terminal congestion or unexpected waiting times before berthing or before starting loading/discharging, port/terminal productivity below expectations, access channels, maritime passages, and chance (such as weather conditions, on-route mechanical problems). A study by Chung and Chiang (2011) indicates that the most substantial object is 'process management in shipping lines' and that the critical criteria were 'well-arranged time window', 'transship arrangement', 'planning the suitable ports', 'planning the berth and warehouse beforehand', and 'control and management staff in the terminal'. The affecting factors of schedule and transit time reliability in liner shipping indicated in the related literature are visualized in Figure 1.

There has been a lack of studies in maritime transport, especially on the topics that exhibit the existing state of shipping lines' in terms of transit time reliability performance and the influencing factors of transit time reliability. All these conditions constitute the primary motivation of the study. The main problem of this study is the transit time reliability of shipping lines' in liner shipping. From a regional perspective, the problem has been analyzed over the shipping lines using Turkish Ports, and their performance in terms of transit time reliability has been determined. Afterward, the difference in transit time deviations and reliability according to the service type (whether the service is a transshipment or direct service), vessel characteristics, and weather conditions were investigated.

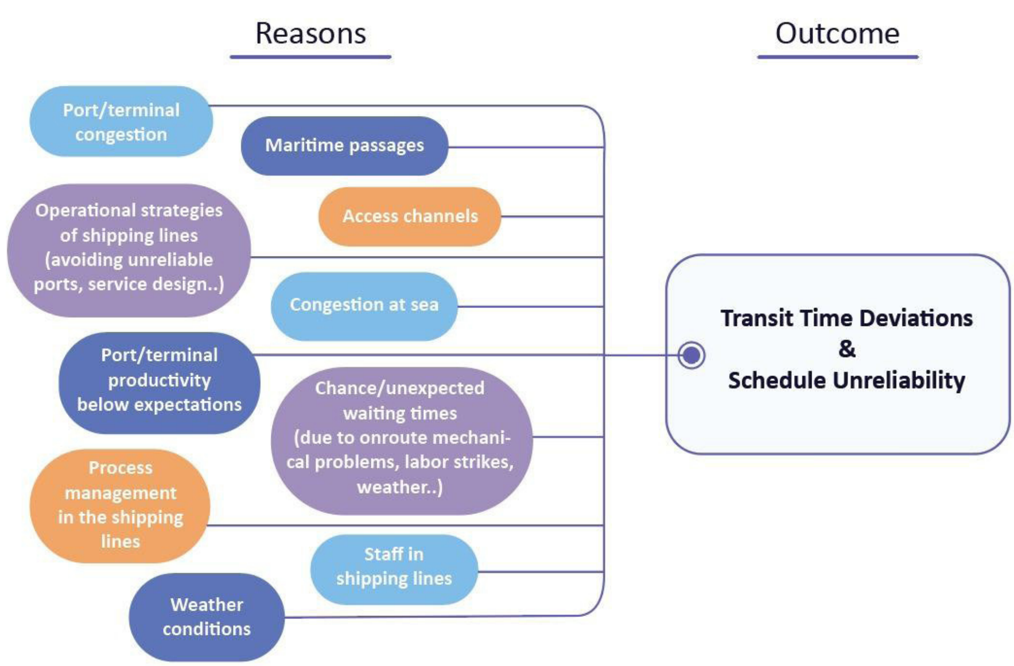

Figure 1 The affecting factors of schedule and transit time reliability

Source: Notteboom, (2006), Vad Karsten, Vernimmen, Dullaert and Engelen (2007), Chung and Chiang (2011), Qi and Song (2012), Brouer and Pisinger, (2017), and Abioye et al. (2019).

3 Methodology

3.1 Objectives

Many factors affect the transit times that global shipping lines announce in vessel schedules before a voyage. It is crucial for all supply chain actors that shipping lines respect these times. Based on actual transportation data, to investigate schedule reliability in liner shipping and the factors that may affect transit time reliability, this study evaluates *the transit time reliability performance of shipping lines using selected Turkish ports.*

3.2 Model development and hypothesis

To fulfill the first of the research aims, estimated transit times that the shipping lines reported in the vessel schedules and actual transit times that were realized as a result of the transportation were examined between the routes determined. These data were used to evaluate the current situation in transit time reliability. Next, factors that affect transit time reliability were evaluated. As stated in the literature, many factors affect transit time and reliability, only some of which are under the control of shipping lines. These factors include service port/terminal congestion, maritime passages, operational strategies of shipping lines (such as avoiding unreliable ports and service design), access channels, congestion at sea, port/terminal productivity below expectations, chance/unexpected waiting times (such as due to on-route mechanical problems, labor strikes, weather), process management in the shipping lines, staff in shipping lines and weather conditions (Notteboom, 2006; Vad Karsten, Vernimmen, Dullaert and Engelen 2007; Chung and Chiang, 2011; Qi and Song 2012; Brouer and Pisinger, 2017 and Abioye et al., 2019). However, as a limitation of the study, researchers attempted to work on four factors/variables that can be accessible for the sake of the reliability of the analysis. This limitation is due to the difficulty of collecting such data and the reliability of this data. By considering this fact, our analysis can be considered an exploratory study for further studies. Besides, these factors in the literature were determined mainly by surveys or expert opinions. In contrast, this study intends to test these factors in the literature on actual data. For this reason, factors that can be reached on the actual transportation data among accepted factors in the literature were examined in this study. Information related to these factors is directly linked to the actual transportation data. It aimed to investigate whether the transit time deviations differ according to these factors that affect the transit time and thus discuss its effect on the transit time reliability. Based on the current transport, this study is regarded to close the gap in evaluating the actual situation in transit time reliability in liner transportation.

The literature indicates that the operational strategies of shipping lines are one of the factors affecting schedule reliability in liner shipping. Network and service design of shipping lines will also be effective in terms of reliability as a part of these strategies. In service design, it is important to plan a service as either a transshipment or a direct service. For this purpose, the H_1 hypothesis was created to investigate whether the reliability of direct and transshipment services is the same. H_1: Transit time deviations of shipping lines' services differ according to whether the service is a transshipment or direct service (according to the service type).

Several studies have mentioned that seasonal conditions theoretically affect program reliability (Notteboom, 2006; Vernimmen, Dullaert and Engelen 2007; Gaonkar et al., 2011; Qi and Song 2012 and Abioye et al., 2019). The H_2 hypothesis was created to evaluate the effects of the adverse weather conditions of the winter season on liner shipping. H_2: Transit time deviations of shipping lines' services differ according to the season.

In the literature, no attention has been paid to the effect of ship characteristics on transit time reliability. Although Gaonkar et al., (2011) stated the effect of vessel age on operational reliability in their studies, they associated vessel age with safe mission criteria of operational reliability, not timeliness criteria. In this study, to investigate the effect of vessel characteristics on transit time reliability. The effect of growing vessel sizes on maritime transport is controversial. Sea Intelligence (2021) indicated that after the Ever-Given ship ran aground in 2021, causing maritime traffic to stop for 6 days, there was an opinion among some cargo owners and industry that larger container ships resulted in poor service quality. From this discussion, hypothesis H_3 emerged. H_3: Transit time deviations of shipping lines' services differ according to the twenty-foot equivalent unit (TEU) capacities of the vessels used in transportation. Thanks to the study, this issue will be evaluated in terms of the reliability of services. It was questioned whether the reliability performance of old and new ships was the same, and the H_4 hypothesis was formed. H_4: Transit time deviations of shipping lines' services differ according to the vessels' age used in transportation.

3.3 Population and sampling

The data analyzed in the research were obtained from the database of a global digital container tracking platform. On the platform, users can see the information of which shipping lines provide service between two ports and access the transit time information of the services. Estimated transit time information is transferred to the platform's database from the shipping lines' schedules, and the actual transit times are also recorded. From a regional perspective, the problem has been analyzed over the shipping lines using Turkish Ports. In the transports examined within the scope of the research, the loading ports are Ambarli (Istanbul), Aliağa (Izmir), and Mersin, and discharging ports are Antwerp and Felixstowe. All shipping lines on the determined route were evaluated (Arkas, Cma Cgm, Cosco, Evergreen, Hamburg Sud, Hapag Lloyd, Msc, One-Line, Ocl, Sealand, Turkon, Yang Ming, and Zim Line). This study desired to approach this global problem locally; therefore, the analysis was made over Turkish ports. At the same time, transports from and to the Turkish port are predominant on the platform the data is obtained. These selected loading ports are among the most used ports in Turkey's export maritime container transportation. Since the characteristics of the ports subject to the research are similar, they were preferred, and it was aimed to reduce the port effect in comparisons. Likewise, discharging ports are among the ports where Turkey frequently transports containers and, simultaneously, are the ports with the most excess transport data in the platform's database.

3.4 Data analysis

Outliers were discarded using the interquartile range (IQR) method. In total, 5082 transport data were examined. These transports were carried out in 2019 (n = 1094), 2020 (n = 1940), and 2021 (n = 2046). A calculation was made by taking the absolute value of the difference between the estimated and actual transit times to calculate the transit time deviations. In addition to late arrivals, a vessel's arrival at the port before the estimated transit time is also considered a deviation. Transit time deviations were standardized to compare the routes with different transit times, and for this, analyzes were carried out by determining the transit time deviation ratios. This ratio was calculated by dividing the transit time deviations by the estimated transit times. Because the sample size is large and has 5080 members, and because of the Central Limit Theorem, the distributions of variables can be considered to behave as usual. Therefore, parametric tests can also be used. Independent sample t-test and Welch's ANOVA test were applied to examine factors affecting transit time reliability. The homogeneity of variance, which is the assumption of ANOVA, was tested for each variable, and Welch's ANOVA test was used because the variances were not homogeneous. P-values < 0.05 were considered statistically significant. SPSS 26 was used for all analyses.

4 Findings

4.1 Transit time reliability

In this section, route-based and shipping line-based statistics will be included in the context of transit time reliability. The number of on-time, late, and early-arriving transports is shown in Figure 2. Of 5080 transports, 2290 arrived on time, 2531 arrived late, and 259 arrived earlier than estimated. Figure 3 shows the change in transit time deviations by year. While the average transit time deviation was 0.73 in 2019, 1.01 in 2020, and 1.83 in 2021.

Table 1 shows the number of observations, average estimated and average actual transit time, and average transit time deviations for the transports of all shipping lines serving each route. Accordingly, in Aliağa-Felixstowe transports, it is seen that the shipping line with the highest transit time deviation is Sealand, with an average of 1.15 days, and the shipping line with the lowest transit time deviation is the Oocl line, with an average of 0.24 days. When an evaluation is made based on routes – without any shipping line distinction – the best service was given on the Aliaga-Felixstowe route, with an average of 0.97 days transit time deviation. For the Ambarli-Antwerp route, Zim Line provided eight services with an average of 4.25 days transit time deviation, and Yang Ming provided 25 services with an average deviation of 1.24 days. When an evaluation was made based on the total of all lines' transports, the best service was given on the Ambarli-Antwerp route, with an average of 1.66 days transit time deviation. For the Ambarli-Felixstowe route, Zim Line had an average transit time deviation of 2.38 and was the least reliable service Oocl and Msc had the lowest average transit time deviation average with 0.90 and 0.95. It is seen that on the Ambarli-Felixstowe route, the average transit time deviation in total when considering without shipping line distinction was 1.17 days. On the Mersin-Antwerp route, Oocl had the highest transit time deviation average of 2.88 days and Sealand had the lowest average of 0.99 days. When an evaluation is made based on the routes without any shipping line distinction, it is found that average transit time deviation in Mersin-Antwerp route was 1.40 days.

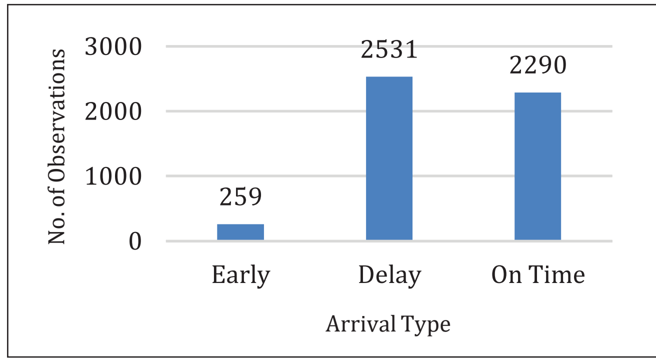

Figure 2 Transit time reliability performance

Source: Authors

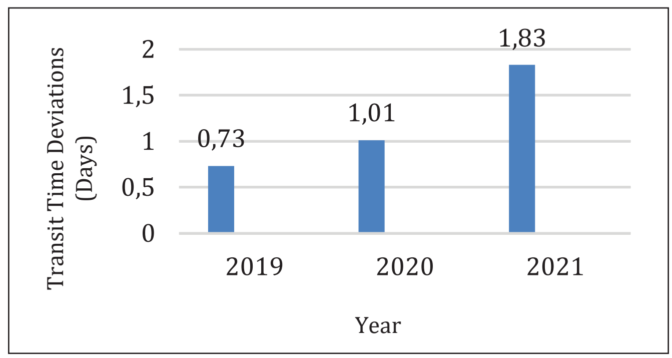

Figure 3 Transit time deviations by years

Source: Authors

Table 1 Transit time reliability performance of shipping lines by routes

Route		Arkas	Cma Cgm	Cosco	Evergreen	H.Sud	Hapag Lloyd	Msc	One Line	Oocl	Sealand	Turkon	Yang Ming	Zim	Total
Aliaga-Felixstowe	Average Actual TT (day)	0	13.43	9.76	0	10.98	9.83	10.89	0	8.53	12	11.32	8.97	0	10.95
	Average Estimated TT (day)	0	12.39	9.08	0	10.07	9.72	9.95	0	8.41	10.9	10.61	8.53	0	10.18
	Average Deviation (day)	0	1.07	0.87	0	0.95	1.06	0.96	0	0.24	1.15	0.96	0.5	0	0.97
	No of Obs.	0	120	125	0	199	180	257	0	17	181	85	62	0	1226
Ambarli-Antwerp	Average Actual TT (day)	17	18.56	20.13	0	21.81	18.42	13.86	14.78	20.1	22	21.02	18.72	38.13	18.33
	Average Estimated TT (day)	17	17.64	18.23	0	20.48	17.36	12.74	13.33	18.41	20.32	19.49	17.8	33.88	16.91
	Average Deviation (day)	2	1.31	1.94	0	1.79	1.5	1.26	2.33	1.82	2.2	2.05	1.24	4.25	1.66
	No of Obs.	6	36	114	0	52	92	302	9	237	69	57	25	8	1009
Ambarli-Felixstowe	Average Actual TT (day)	0	18.19	14	0	15.03	13.21	11.24	0	12.94	15.66	14.63	13.93	26.19	13.79
	Average Estimated TT (day)	0	17.22	12.88	0	13.90	13.28	10.38	0	12.14	14.3	13.97	12.91	23.81	16.60
	Average Deviation (day)	0	1.03	1.3	0	1.2	1.29	0.95	0	0.9	1.4	1.22	1.2	2.38	1.40
	No of Obs.	0	37	250	0	202	175	345	0	182	202	32	46	21	1492
Mersin-Antwerp	Average Actual TT (day)	17.06	14.07	21.23	21.73	17.82	17.56	17.42	14	22.12	15.74	0	20.95	26.69	17.68
	Average Estimated TT (day)	16.25	13.25	19.71	20.31	17.22	16.62	16.17	12.81	19.54	14.8	0	19.36	26.54	16.60
	Average Deviation (day)	2.31	1.11	1.82	1.88	1.31	1.22	1.3	1.41	2.88	0.99	0	1.75	2.15	1.40
	No of Obs.	36	142	136	28	252	85	252	54	26	217	0	114	13	1353

Table 2 Transit time deviations based on the shipping line

Carrier	Average Actual TT	Average Estimate TT	Average Deviation	Number of Observations
Arkas	17.05	16.36	2.26	42
Cma Cgm	14.78	13.85	1.10	335
Cosco	15.84	14.58	1.44	625
Evergreen	21.73	20.31	1.88	28
Hamburg Sud	15.38	14.49	1.21	705
Hapag Lloyd	13.66	13.31	1.23	532
Msc	13.19	12.16	1.11	1156
One Line	14.11	12.89	1.54	63
Oocl	16.97	15.63	1.46	462
Sealand	15.36	14.17	1.28	669
Turkon	15.10	14.14	1.37	174
Yang Ming	16.41	15.28	1.28	247
Zim	28.62	26.57	2.67	42

Source: Authors

The transit time deviation performance of shipping lines was evaluated (Table 2). Zim made 42 transports and provided the least reliable service, with an average transit time deviation of 2.67. For this route, the Cma Cgm line performed 335 transports and provided the most reliable service, with an average transit time deviation of 1.10.

4.2 Hypothesis Tests

In this section, analyses have been carried out and presented to test shipping lines' transit time deviations according to service type (whether the service is a transshipment or direct service), season, vessel TEU capacity, and vessel age variables. The results of the Independent Sample T-Test, Welch's ANOVA Test, and Tamhane's T2 Post-Hoc Test are shown in Table 3.

Independent Sample T-Test was performed to compare the transit time deviations according to the service type. A significant difference was found between the transit time deviations of the direct and transshipment services (t -4.011, p=0.000<0.05). Accordingly, the H_1 hypothesis is accepted. Transit time deviations with transshipment services ($\bar{x}$ = 0.1241) are higher than in direct services ($\bar{x}$= 0.0938). Accordingly, the H_1 hypothesis is accepted.

When using an independent sample t-test applied to examine the effect of seasonal conditions, there was a significant difference between the groups for the transit time deviations of the transportations made in the winter season and the transportations made in the other months (t = 4.440, p = 0.000<0.05). The transit time deviations of transportations carried out in winter ($\bar{x}$ = 0.1107) are higher than in other seasons ($\bar{x}$ = 0.0915). Accordingly, the H_2 hypothesis is accepted.

Based on vessel TEU capacity and vessel age factors, the data obtained from Welch's ANOVA test are presented in Table 3. Before starting the analyses, groupings were made using the literature for vessel age and TEU classifications and considering the available data to be analyzed (Eyres and Bruce, 2012; Equasis, 2020; UNCTAD, 2021; Statista, 2022). Vessels were divided into three TEU capacity groups (0–3000, 3001–5000, and 5001–10000 TEU) and four age groups (0–9, 10–14, 15–19, and 20–30). The number of observations in each group is shown in Table 3. There is a statistically significant difference between the transit time deviations among the vessels' TEU capacity (F = 7.096, p = p<0.000<0.05). Also, there is a statistically significant difference between the transit time deviations according to the age of the vessels' (F=4.188, p = 0.000<0.05). Therefore, hypotheses H_3 and H_4 are accepted.

Tamhane's T2 post-hoc test was applied to determine which groups the difference arises from, and results related to vessel TEU capacity and vessel age factors are presented in Table 3. It is determined that the vessel groups in the ranges of 0-3000, 3001–5000, and 5001–10000 TEU were statistically significantly separated (p = <0.05). The vessels' transit time deviations were higher in the 0–3000 TEU capacity range than for the other groups. The transit time deviations of vessels in the 3001–5000 TEU capacity range were the lowest. Regarding vessel age factor, it is observed that the vessels in the 20–30-year-old vessels differed significantly from those in the 10–14 and 15–19-year-old groups. The transit time deviations were higher for the 20-30-year-old vessels (p ≤ 0.05).

Table 3 Independent sample t-test, Welch's ANOVA, and Tamhane's T2 post-hoc test results

Independent sample t-test						
Service Type		**N**	**Mean**	**Sd**	**t**	**p**
Direct		4795	.0938	.11521	-4.014	.000
Transshipment		285	.1241	.12406		
Season		**N**	**Mean**	**Sd**	**t**	**p**
Winter		1052	.1107	.12818	4.440	.000
Other Seasons		4028	.0915	.11217		
Welch's ANOVA						
Source		**Sum of Squares**		**df**	**F**	**p**
TEU		.637		2	23.072	.000
Age		.287		3	7.029	.000
Tamhane's T2 post-hoc test						
Age (i)	**Age (j)**	**N**	**x̄**	**Mean Dif.**	**S.E**	**p**
0-9	10-14	2408	.0935	.01831	.01229	.594
	15-19	1600	.0891	.02279	.01241	.349
	20-30	979	.1093	.00253	.01263	1.000
10-14	0-9	93	.1118	-.01831	.01229	.594
	15-19	1600	.0891	.00449	.00373	.790
	20-30	979	.1093	-.01577*	.00441	.002
15-19	0-9	93	.1118	-.02279	.01241	.349
	10-14	2408	.0935	-.00449	.00373	.790
	20-30	979	.1093	-.02026*	.00473	.000
20-30	0-9	93	.1118	-.00253	.01263	1.000
	10-14	2408	.0935	.01577*	.00441	.002
	15-19	1600	.0891	.02026*	.00466	.000
TEU (i)	**TEU (j)**	**N**	**x̄**	**Mean Dif.**	**S.E**	**p**
0-3000	3001-5000	1367	.0827	.05904*	.00948	.000
	5001-10000	3530	.0980	.04373*	.00921	.000
3001-5000	0-3000	183	.1418	-.05904*	.00948	.000
	5001-10000	3530	.0980	-.01530*	.00358	.000
5001-10000	0-3000	183	.1418	-.04373*	.00921	.000
	3001-5000	1367	.0827	0.1530*	.00358	.000

Source: Authors

5 Conclusion and Discussion

With the diversification of technologies, customers' transparency and visibility demands are increasing. Customers are pressuring shipping companies for a more dependable service because of their increased awareness and willingness for a more transparent system. Shipping lines are expected to achieve high transit time reliability. However, the complex nature of transportation networks and the large number of parties involved make time management difficult in liner shipping. During transportation organization, vessels may encounter many different problems at sea or in ports, and these problems can cause vessels to be delayed. The delays experienced directly affect all parties in the logistics processes and the businesses' supply chains.

The paper analyses the current performance of shipping lines' transit time reliability. Within the scope of the analysis, 5080 numbers of transports covering the years 2019, 2020, and 2021 were examined. Transit time deviations were evaluated, considering both early arrivals and delays. However, it is seen that late arrivals account for most transit time deviations. Only 45% of the transport vessels arrived on time. In the remaining transports, 5% of vessels arrived early, and 50% arrived with delay. As well as the late arrival of shipments, early arrival can create problems for businesses. Since all planning processes are made by taking ETA information into account, early arrivals may cause problems in business processes and extra costs. When the annual evaluation of the transit time performances of shipping lines' was made, it was seen that the rate of vessels arriving on time among all transports was rates of 58% in 2019, while it was 55.9 % in 2020. However, looking at the year 2021, it is seen that this rate has decreased to 27.8 %. In 2021, shipping lines' transit time reliability performance deteriorated significantly. These results, which show that the transit time deviations increased in 2021, which is consistent with the Sea Intelligence (2022) statistics. Among the shipping lines evaluated on the selected routes, Cma Cgm and Yang Ming had the best on-time arrival rates (51%, N=335; 50.661, N=247, respectively). Arkas (19 %, N=42) and Zim (21.4 %, N=42) provided the lowest on-time arrival rates and the least reliable services. The Aliaga-Felixstowe route had the lowest transit time deviation, and Ambarli-Antwerp had the highest.

The results showed that the transit time reliability of the line carriers is low. Adding more buffer time to vessel schedules during planning would help to improve on-time arrival rates in the face of unforeseen events. Buffer time is the time added to a task to adapt to the possibility that conditions may not be as planned. In this way, shipping lines can avoid the cumulative effect of a delay in one leg of the transport affecting the subsequent leg of the journey.

For the second aim of this study, transit time deviations of the services in liner shipping were examined in terms of TEU capacity, vessel age, seasonal conditions, and the type of service (direct or transshipment). It has been found that more transit time deviations occur in transshipment services than in direct services. This supports the effect of port/terminal conditions on transit time and program unreliability, which Notteboom (2006), Gaonkar et al., (2011) and Chung and Chiang (2011) have addressed. Direct services reduce the possibility of delays. With an indirect service, with one or more transfers, the chances of delays may be possible to grow exponentially. Therefore, shipping lines must offer direct services as much as possible. Besides, shippers must prefer direct services first to reduce delay and reliability risk. In the test of whether the transit time deviations differ according to the season, it has been observed that more transit time deviations occur in the transports carried out in the winter season than in other seasons. Adverse weather conditions, such as the wind in the winter, might cause disruptions in ports or during the voyage at sea. Multiple studies with surveys and similar methods, (Notteboom 2006; Vernimmen, Dullaert and Engelen 2007; Gaonkar et al., 2011; Qi and Song 2012; and Abioye et al., 2019) have proposed that weather conditions theoretically affect transit time and program reliability. The result that emerged in this study proves the mentioned studies in practice. Changes in the weather can occur suddenly and may be unpredictable. Such changes in wind or sea conditions can adversely affect port operations and visibility at sailing. Since all these situations may cause deviations in transit times, during the planning process, consideration of the effects of the season and unpredictable situations is crucial. Providing sufficient buffer time is critically important.

In the evaluation of transit time deviations in terms of vessel age, it was determined that the vessels in the 20-30 age group, which are the oldest vessels, differed statistically significantly from the vessels in the 10-14 and 15-19 age groups and their transit time deviations were higher. Gaonkar et a., (2011) also stated that vessel age affects the reliability of the maritime transport system. Young vessels are expected to outperform older vessels. As vessels age, they are more prone to deterioration, creating a problem, and their overall performance may be affected. To overcome this situation, shipping lines may attach importance to keeping the average age of the vessel fleets young. To understand the effect of vessel size, in the test of whether the transit time deviations differ according to vessel TEU capacity, the transit time deviations of the vessels in the 0–3000 TEU capacity range were higher than for the other groups. It is seen that smaller feeder ships in the range of 0–3000 serve with lower transit time reliability. Sea Intelligence (2021) stated that, after the Ever Given ship ran aground in 2021, causing maritime traffic to stop for 6 days, there was an opinion among some cargo owners and industry that larger container ships resulted in poor service quality. The size effect of container vessels is a long-debated issue in the industry. The results demonstrate that the assumption that larger vessels are less reliable is incorrect.

According to the analysis results, approximately 55 % of the vessels do not arrive on time. This ratio shows that the transit time reliability of shipping lines is low. Shipping lines must increase their time management skills. When it is understood that vessels will deviate from the transit time, the shipping line must have planned how to compensate for this beforehand. Transit time reliability is one of the most critical service quality indicators of shipping lines. It has been reported that shippers consider transit time reliability in their carrier selection decisions in the literature. A shipping line may be serving on a route with a shorter transit time than its competitors. However, if this shorter transit time is provided with deviations from the estimated transit times, that is, if the transit time reliability is low, this may prevent it from gaining an advantage over its competitors that serve longer transit times. It can be more critical to how reliable the service is in this regard rather than how short the transit times are for shippers.

In order to investigate schedule reliability in liner shipping, based on current transportation data, this study attempts to evaluate the transit time reliability performance of shipping lines and to examine the factors that may affect transit time reliability. The research results will contribute to various aspects of the literature and the private sector. It is aimed that the research results will contribute to the lack of studies in the transit time reliability literature. Based on the current transports, this study is regarded to close the gap in evaluating the actual situation in transit time reliability in liner transportation. It is regarded that the transit time reliability performances of the shipping lines emerging as a result of the research will contribute to the shippers' carrier selection decisions and supply chain planning processes. These data will also help shipping lines develop strategies to improve service quality. In liner shipping, lines can use these results as a benchmark to evaluate how reliable they are compared to the competition and the factors that affect their transit time reliability. This study can be regarded as an exploratory study for further studies. This study has some limitations as well as strengths. Researchers attempted to work on the four factors that can be accessible for the actual data evaluated for the sake of the reliability of this analysis. Therefore, future studies may include port-related factors to determine the effect of port/terminal productivity on transit time reliability. Also, broader analyses, including multiple countries and regions, would be valuable.

Acknowledgements: We would like to thank the Shipsgo Academy for providing detailed data and support by spending their time on our research.

Funding: The research presented in the manuscript did not receive any external funding.

Author Contributions: İlknur Gizem Yazar Okur, conceptualization, methodology, data collection, data analysis, research, writing, review, and editing. Okan Tuna, conceptualization, methodology, data collection, review and editing, supervision and final validation.

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