Flexible and Adaptive Port Planning

(Sveigjanleg og aðlögunarhæf skipulagsgerð fyrir hafnir)

A Vessel Call and Vessel Size Analysis for the Ports of Ísafjörður Network

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Abstract

Globalization has increased international trade where the contribution of maritime transportation is significant. The projection of future port traffic in terms of vessel call and vessel size provides valuable and fundamental input to capacity planning and management, adjusting the direction of port development.

In this research project, analysis of port traffic is carried out for the Ports of Isafjordur network. The analysis is conducted based on the prediction of port throughput (i.e., containerized and non-containerized cargo, cruise ship call/passenger) in conjunction with port infrastructure (i.e., quay length, water depth).

Using the time series univariate forecasting method, an exponential smoothing model is developed to project the port throughput. Furthermore, primary and secondary data research are used in this research project.

The results show that vessels with a capacity between 800-1200 TEU come into service by 2050 to handle the increasing projected volume of containerized cargo. Furthermore, an increase in service frequency is expected. Cruise ship calls and average size will continue to increase. Large cruise ships can be accommodated in the (developed) Port of Isafjordur, and the increasing number of cruise ships can be serviced by maximum use of Sudureyri, Flateyri, Thingeyri Ports.

This research project provides useful information for port stakeholders to be more knowledgeable about future port traffic. The results support decision making for planning, design, and in time development/adaptation of the port layers including infrastructure, operation, and services.

Keywords: Adaptive Port Planning, Iceland, Port Traffic, Ports of Isafjordur Network

Introduction

Maritime transportation is a crucial component of global trade. More than 80% of the global trade tonnage and 70% of the global trade value are carried by oceangoing vessels around the world (UNCTAD 2016).

Globalization has resulted in international trade growth and consequently an increase in port traffic in terms of vessel calls at ports and vessel size (increased by 1200% in 50 years) (Dulebenets 2018). Increasing demand on the maritime trade and utilization of economies of scale by the shipping companies to reduce the costs per Twenty-foot Equivalent Unit (TEU) (or passenger) -mile, and to increase the operating margins in a highly competitive market, have further increased size of vessels (Haralambides 2019).

The containership size has evolved from about 5500 TEU in 1995 to more than 23,000 TEU in 2019 and Evergreen has placed an order for six ships of close to 24,000 TEU. Ge et al., (2019) stated that an increase to 25.000 TEU still generates economies of scale. In this context, Haralambides (2019) stated that utilization of economies of scale by shipping companies may result in diseconomies of scale in ports.

This increase has imposed pressure on port layers including infrastructure, operation, and services. Shipping companies do not reveal their policies on vessel size due to the fierce competition that exists in the shipping market (Gomez Paz, Camarero Orive, and González Cancelas 2015) and their strategic, tactical, and operational decisions are faced with many uncertainties (Meng et al. 2014).

Cruise companies demand high-quality infrastructure and services for passengers (Gui and Russo 2011). Ports should accommodate cruise ships and handle the significant strain that they place on port facilities and services due to their short turnaround time and services to a large number of passengers.

In this context, port authorities have continuously adopted (and developed) the port layers to satisfy the demands of numerous stakeholders with different spatial and temporal influences (Eskafi et al. 2019) and a variety of, often conflicting, objectives (Eskafi et al. 2020) in this ever-increasing competitive market environment.

Port infrastructure is one of the primary factors that influence the decisions made by shipping companies for the port choice (Guy and Urli 2006). However, decision making for the acquisition of port infrastructure is a challenging task due to its capital-intensive, the long payback period of investment, and the timescale associated development of infrastructure.

Port planning requires complex analytical work to ensure the balance of supply (e.g., port infrastructure) and demands (e.g., safe port traffic) in the volatile environment. Knowledge of port traffic development is critical, as the vessel characteristics have implications for planning and strategic development and adaptation of port layers.

Port traffic forecast is significantly important as decision support in port planning, mitigating the environmental impacts of transport, analyzing port logistics and hinterland transport systems, port traffic management, optimal allocation of port resources (Tavasszy et al., 2015).

There is a need to project the traffic flow that a port can service with adequate safety provisions and acceptable waiting times. Therefore, an integrated approach is developed based on the port throughput, in conjunction with port infrastructure to analyze the port traffic in terms of vessel call and vessel size at the Ports of Isafjordur network.

The result helps to continuously adapt port infrastructure to prevent bottlenecks arising from growing port traffic. This analysis is of great importance to position the port network for sustained growth and maintain its competitive position.

Methods

In this research project, an exponential smoothing model is used to investigate port throughput and thus port traffic development. The exponential smoothing model is a time series univariate forecasting method. The model computes a weighted average of past observations as input to the time series dataset for the prediction of port traffic values. In contrast to simple moving average models that give constant weights to past observed values (or measured values), the weights to past observed values in an exponential smoothing model are exponentially decreasing over time. This means that the exponential smoothing model gives more importance to the recently observed values in the series and the importance of older observed values is exponentially smaller. The weights are dependent on a constant parameter, which is known as the smoothing parameter.

The model combines trend, seasonal, and error components in a smoothing calculation. The trend component indicates the general behavior of the time series. The seasonal component shows the variations related to time. The error component indicates what the trend and seasonal components are not able to explain. The error component is the difference between the original data and the combination of trend and seasonality (Hyndman et al. 2008). The model algorithm is useful for datasets with seasonality.

In this research project primary (e.g., cargo flow data, macroeconomic data) and secondary data (e.g., infrastructure characteristics) research is used. Secondary data research allows the collection of already existing data from several different sources. To collect secondary data, scholarly articles in peer-reviewed literature and official reports and statistics were reviewed. The primary data are collected from the relevant authorities.

The results are discussed based on economic development, port throughput, and port infrastructure as they are the key factors for port traffic analysis and forecast (Haralambides 2019).

Study Area and Data Used

This research project was carried out for the Ports of Isafjordur Network (Hafnir Ísafjarðarbæjar) including the Port of Isafjordur (Ísafjarðarhöfn), the Port of Sudureyri (Suðureyrarhöfn), the Port of Flateyri (Flateyrarhöfn) and the Port of Thingeyri (Þingeyrarhöfn), located in the northwest of Iceland (see Figure 1).

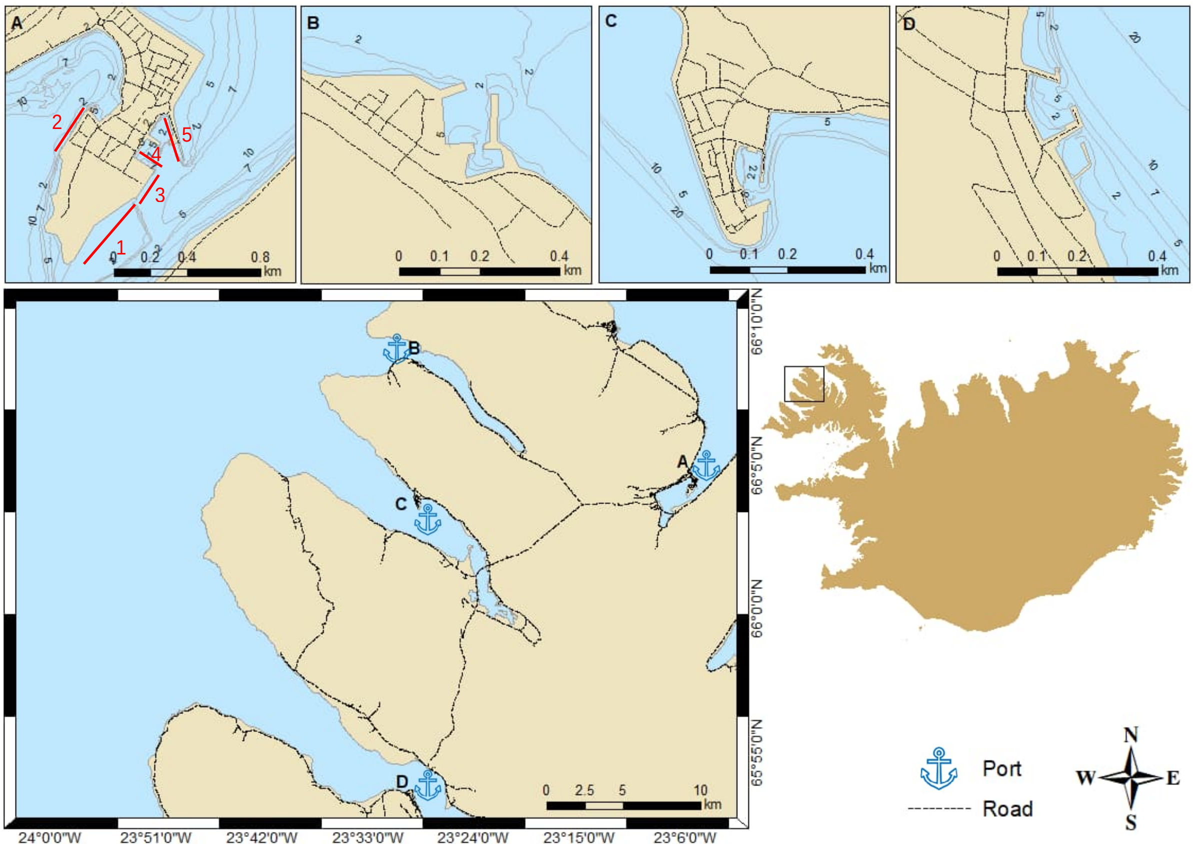

Figure 1. The location of the Ports of Isafjordur Network. The study area is shown on the map of Iceland. A, B, C, and D stand for the Ports of Isafjordur, Sudureyri, Flateyri, and Thingeyri, respectively.

Table 1 gives the infrastructure (i.e., quays) profile of the Port of Isafjordur. The numbers are shown in Figure 1.

Table 1. The quay characteristics at the Port of Isafjordur

No.	Length (m)	Depth (m)
1*	300	10
2	270	10
3	190	7.8
4	120	7
5	70	8

* New development (quay extension), see Figure 1

Figure 2 shows the 3D model of the access channel to the Port of Isafjordur using Surfer 13 software.

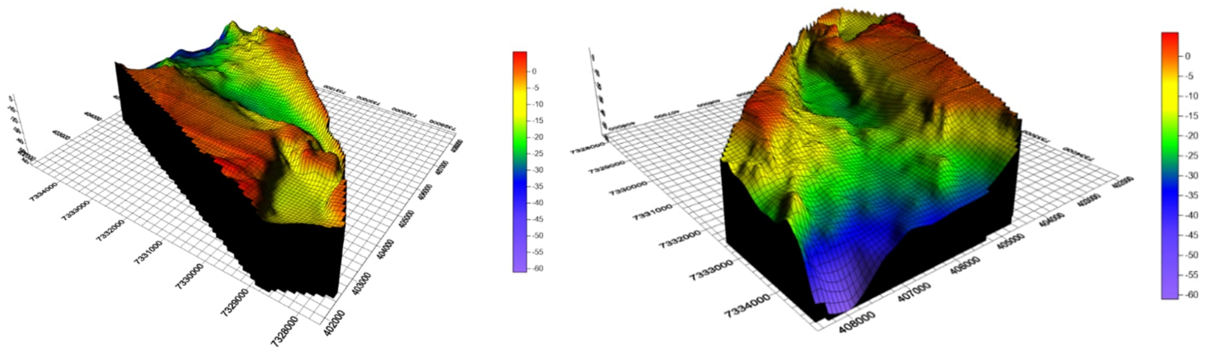

Figure 2. Skutulsfjordur Seabed and access channel to the Port of Isafjordur

The ports in the network are different in size, capacity, function, and navigational conditions. The geo-position of the network and spatial distribution of the ports in the northwest of the country give a strategic advantage to the Port Authority for better services to port users.

The network has a locational advantage as it is:

1- close to a rich fishing ground in the North Atlantic Ocean,
2- with short sailing times to the open sea,
3- located at the main axes of seaborne trade and coastal shipping on a regular basis,
4- surrounded by growing businesses (e.g., aquaculture and relevant value-added activities) (Statistics Iceland Office 2021).

The Port of Isafjordur is the biggest and premier container port in the region and the distribution center for the network. The port has a competitive advantage, due to its infrastructure and services to different types of vessels, among the other ports in the Westfjords region. Given its growing importance as a gateway in the region, and its potential for terminal capacity expansion, the port is positioned to become an important port-of-call in the region. The other three ports (Sudureyri, Flateyri, and Thingeyri) mainly render services and accommodation to fishing boats and occasionally to smaller cruise ships, recreational boats, and cargo vessels.

Non-containerized cargo flow through the port network is mainly categorized as fuel oil, road construction and maintenance materials, fertilizer and fish feed, marine products, and industrial materials (Eskafi et al. 2021a). Eskafi et al. (2021a) Used the mutual information to show the composition of the non-containerized cargo at the Port of Isafjordur (Figure 3). These cargos are measured in tonnes. Containerized cargo is based on a Twenty-foot Equivalent Unit (TEU).

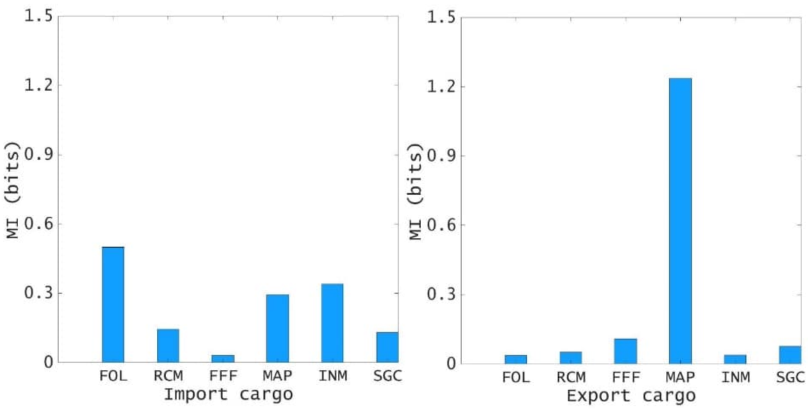

Figure 3. The mutual information (MI) values of the non-containerized cargos for export (left) and import at the port (right).

In Figure 3, the cargos are fuel oil (FOL), road construction and maintenance materials (RCM), fertilizer and fish feed (FFF), marine products (MAP), industrial materials (INM), and small general cargo (SGC). As is shown in Figure 3, the main export cargo is marine products, whereas the aggregation of fuel oil, marine products, and industrial materials can be indicated as credible import cargo.

Coastal shipping and road transportation are the two transport modes that connect the port network to its hinterland, which is the whole country. The port network plays a significant role in the logistic chain of the region as well as the country.

Currently, the trade volume and infrastructure have limited the use of vessel capacity to 880 TEU. There are three separate (bi-) weekly-frequency deployments calling at the Port of Isafjordur (Figure 4).

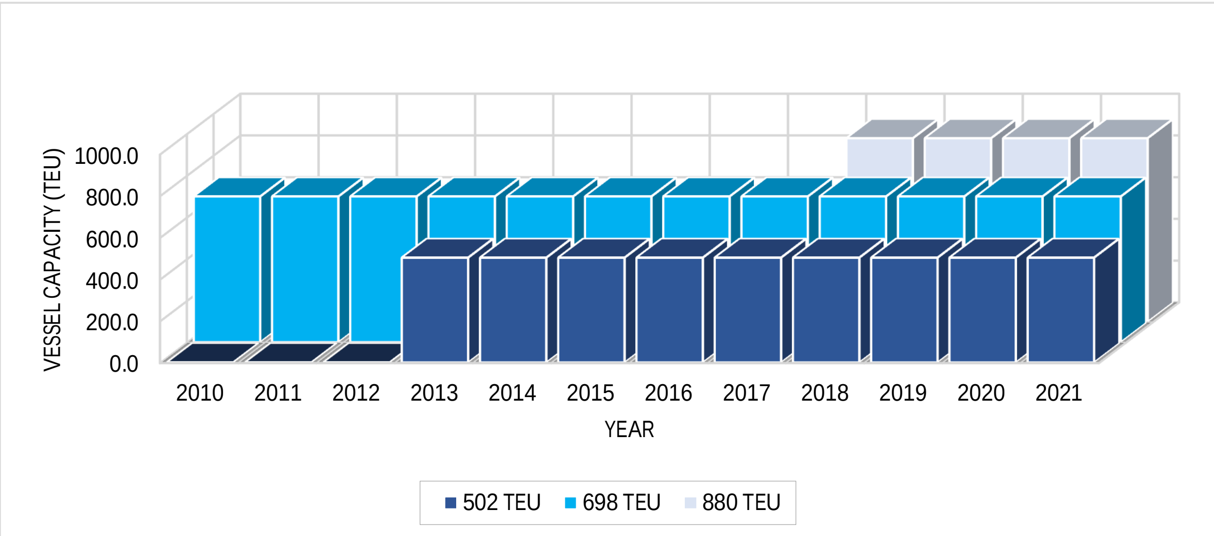

Figure 4. The capacity of vessels that call at the Port of Isafjordur

The trend towards increasing vessel size in the port is evident. Table 2 gives the list of vessels that are in service and call at the Port of Isafjordur.

Table 2. The characteristics of vessels that call at the Port of Isafjordur

No.	Name	Capacity (TEU, [mt])	Length Overall (m)	Beam (m)	Draught (m)	
1	Lagarfoss	880	140.68	23.53	9	
2	Selfoss	698	129.6	20.82	7.2	
3	Hoffell	502	100.6	18.8	6.9	
4	Keilir (Oil carrier)	600	45.973	9.7	3.5	

The Port of Isafjordur in the network is the third busiest port of call for cruise ships in Iceland with a considerable increase in the number of cruise calls in the last few years. In 2018, the fourth largest cruise ship in the world, the MSC Meraviglia, had three calls at the network (Isafjordur Port Authority 2020). In the same year, the port network had the highest proportion of its revenue from cruise ships, and it accounted for 46% of the port network's revenue. This income was also important for the Port Association of North Iceland (Hafnasamlag Nordurlands) since it amounts to 34% of the Association's income (Port Association of Iceland 2019). The port network is a major contributor to the economy of the municipality. In 2019, about half of the revenue (GDP) of the municipality came directly from port revenue (Isafjordur Port Authority 2020).

Small ports do not meet the requirements of large vessels (i.e., container and cruise ships) and the number of passengers. The Isafjordur Port Authority has decided to develop the Port of Isafjordur (i.e., deeper water and longer quay) to satisfy the increasing demands of cruise ships as well as other port users. The port development started in 2020 (Figure 5).

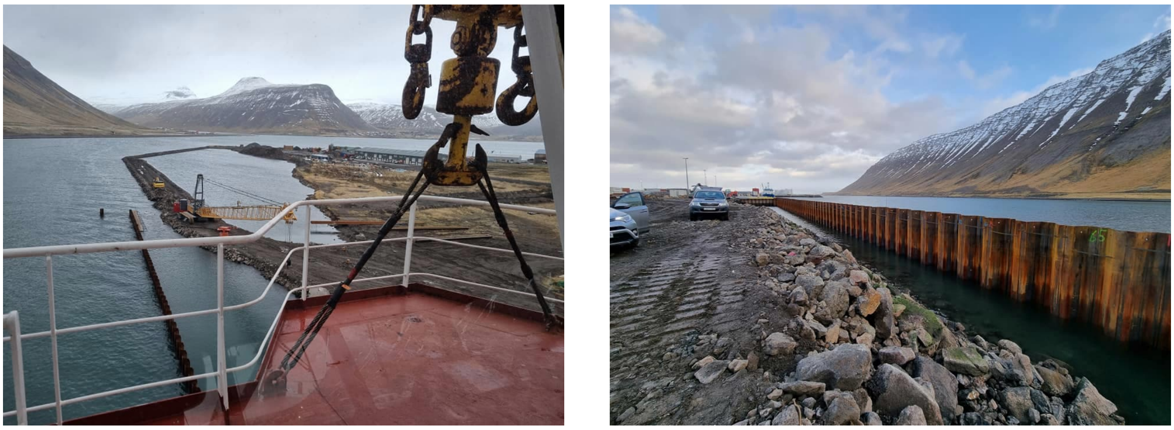

Figure 5. Extension of the quay at the Port of Isafjordur (photo: Isafjordur Port Authority)

Result and Discussion

Containerized and Non-Containerized Vessels

The basic premise in the port traffic in terms of vessel call and vessel size at ports is dependent on 1- anticipated cargo/container throughput which is in turn driven by the influential projected macroeconomic variables (Eskafi et al. 2021b); 2- characteristics of the port layer including infrastructure, operation, and services. This is because different vessels have different sailing requirements and restrictions in different port layers; 3- other uncertain factors based on functions of the port (Eskafi et al., 2021c). In the context of uncertainty, Meng et al. (2014) stated that decision making in shipping companies is confronted with many uncertainties including strategic (e.g., fleet size and mix, alliance, network design), tactical (e.g., frequently, determination, fleet development, speed optimization, schedule construction), operational (e.g., cargo booking, cargo routing, rescheduling).

Figure 6 shows the historical and forecast of containerized throughput at the Port of Isafjordur.

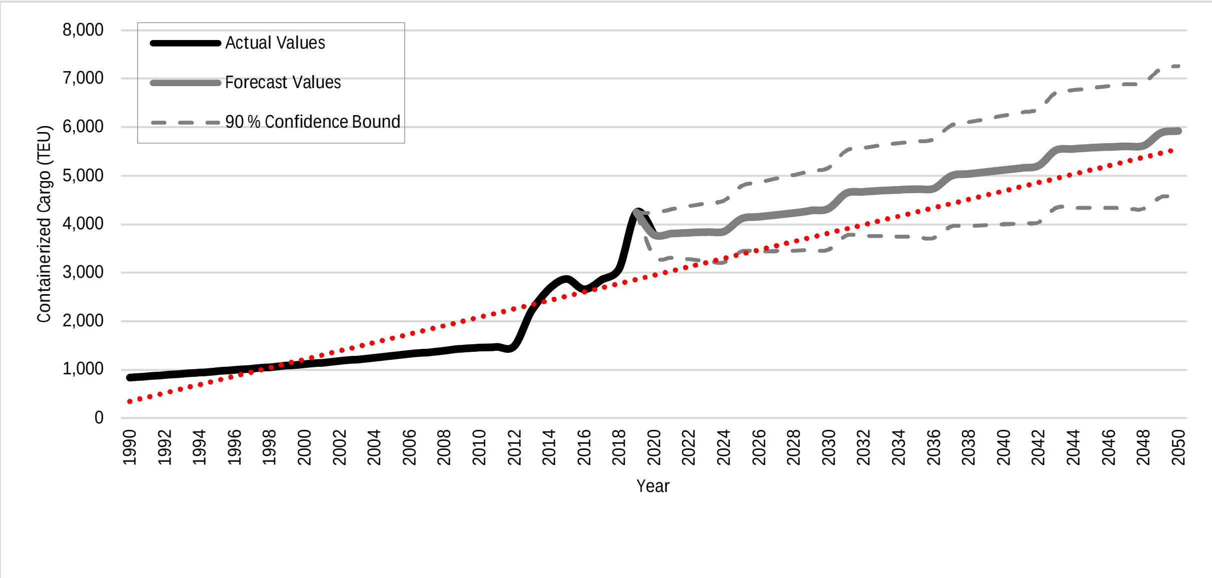

Figure 6. Historical and forecast of containerized port throughput

As depicted in Figure 6, the containerized port throughput has been generally growing, since 1990. The container component forms a large and growing share of the port cargo fleet. Economic growth and containerization should be the reason for this growth (Eskafi et al. 2021d). The significant jump in the port throughput after 2012 could be due to rapid growth in aquaculture, especially the salmon industry in the Westfjords region. The fast-growing aquaculture drives the growth of relevant activities including marine production and industrial equipment manufacturing. Furthermore, another shipping company (additional to the first one) started calling at the Port of Isafjordur in 2013.

However, as depicted in Figure 7, non-containerized port throughput shows a decreasing trend until 2012. The main reason could be the continuous growth in the use of containers for transporting goods.

Two shipping companies maintain the service frequency (flow of containerized and non-containerized cargo) by providing 1- bi-weekly shipping service, and 2- two out of every three weeks shipping service.

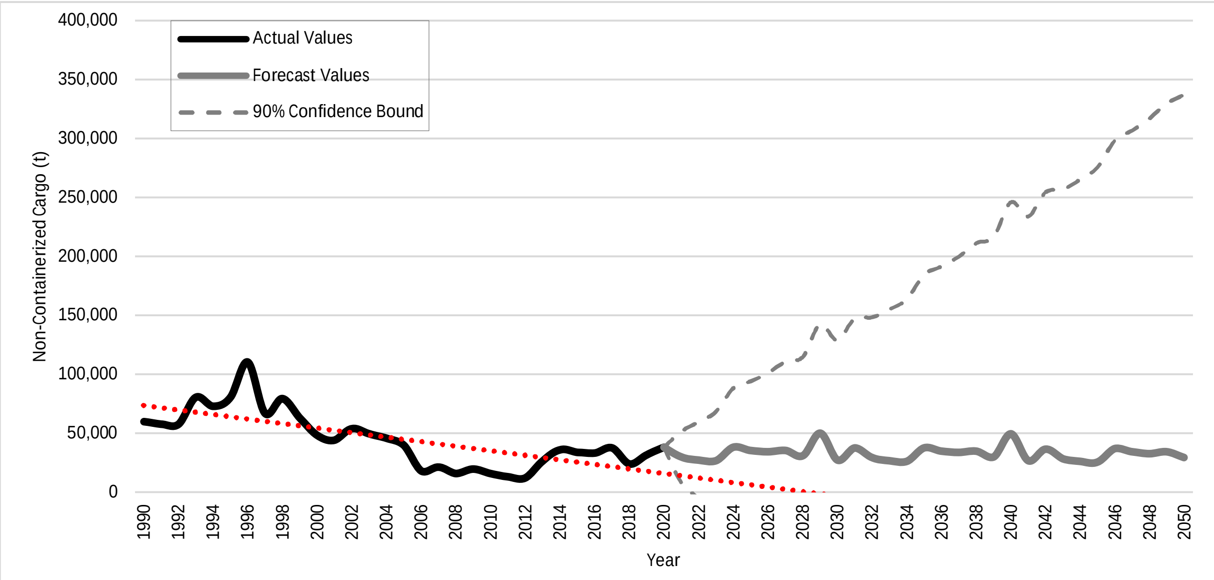

Figure 7. Historical and forecast of non-containerized port throughput

As the majority of trade (i.e., import and export) to Iceland is to the port in Reykjavik, the world trends in shipping may not have any immediate impact on the shipping trends (in terms of vessel call and vessel size) at the Port of Isafjordur. Furthermore, future cargo/container shipping services at the port in the next 30 years are most likely to be determined by trade demand rather than by technological developments.

Vessels with capacities in the range of about 1000 TEU (with the current service frequency) may start to enter cargo/containership fleets in 2030. This range appears to be the most flexible in terms of the port infrastructure and the market they can service. Between 2030 and 2050 in each year the average ship capacity may be increased by about 80 TEU. In 2050, the vessel capacity can be dominated in the range of 800-1200 TEU. Even with increased ship size, an increase in service frequency is expected. Shipping companies deploy large vessels to benefit from economies of scale, emission reduction, and a decrease in fuel consumption reduction in unit costs during the voyage. However, the deployment of large vessels not only imposes pressure on port infrastructure and operation but also leads to congestion, safety, and efficiency issues at the port. Although the current capacity (wet and dry areas) of the Port of Isafjordur (including the new development) may fulfill the need of vessels, the operational and service facilities/requirement should strategically be upgraded during the projected lifetime.

Oil Carrier

The Icelandic government has adopted an action plan on climate change, to reduce greenhouse gas emissions by 40% before 2030 and to achieve carbon neutrality before 2040 under the Paris Agreement (Icelandic Ministry for the Environment and Natural Resources 2020). Furthermore, European policies emphasize the Paris agreement on reducing carbon emissions, limiting fossil fuel consumption, moving towards optimized use of fuels, developing alternative sustainable fuel production and renewable energy activities in ports.

Black oil use in Icelandic territorial waters has been prohibited from 2020 (Regulation no. 124/2015, Iceland). Furthermore, the export of technology and knowledge in the field of renewable energy from Iceland (nearly 100% of electricity and 75% of total energy is from renewable sources) move the industries toward the application of renewable energy (Icelandic Ministry for the Environment and Natural Resources 2007). Energy transition results in a shift from oil to renewables.

As shown in Figure 8, a long-run decline in oil throughput is evident. This decline in oil throughput and storage results in a decrease in the number of oil carriers call. However, oil facilities will stay operational to create hybrid-based renewable fuel use. Therefore, the same vessel (i.e., Keilir, see Table 2) may call at the port entirely over the projected time.

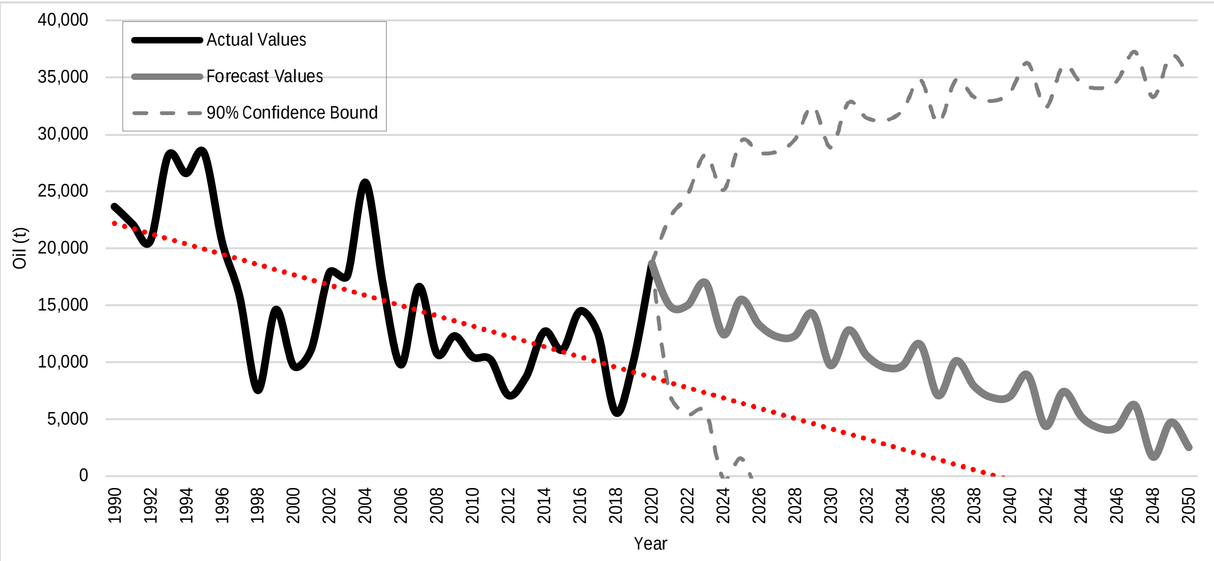

Figure 8. Historical and forecast of oil throughput

The vessel call will depend on the quantity of the local demand and the supplier contract with the local oil retailers. Therefore, the vessel may not be operated on a fixed schedule, but it always brings full cargos (i.e., fuel) to the Port of Isafjordur. The port infrastructure is already sufficient for the vessel.

Cruise Ship

With about twice the growth rate of land-based tourism, the cruise industry was the fastest-growing segment in the travel industry before the COVID pandemic. The growth had affected cruise ship fleets with a greater number of itineraries and bigger vessel sizes.

The unprecedented pandemic has triggered global health and economic crisis undermining the growth prospects of the cruise industry. The COVID pandemic has exerted a profound impact on all maritime sectors, and the cruise industry has been impacted the most due to widespread disruptions that led to the complete cessation of operations.

The COVID pandemic has seriously affected tourism-driven countries. The European Maritime Safety Agency (EMSA) stated that Iceland, Croatia, France, and Spain were the most affected European countries in terms of a decrease in the number of cruise ship calls (EMSA 2021).

As shown in Figure 9, expedition and cruise vessel calls at the Ports of Isafjordur Network have been increasing during the last two decades. The port network was performing strongly in servicing expedition and cruise vessels. Although an increase in expedition and cruise markets was reasonably expected, cruise operators, deferred or canceled their schedules due to the COVID pandemic. Thus, cruise ship calls dropped to zero in 2020 and there were 60 calls in 2021 (the numbers in Figure 9 for these years are the prebooked cruise calls).

However, this market is expected to continue growing. Cruise companies are increasingly looking for new destinations, diversified itineraries to unvisited, smaller, less-well-known, and less-frequented ports of call. Sharpley (2001) stated that the islands have been attractive destinations due to their unique climates and physical characteristics. Furthermore, there is a possibility for short stay calls in the port network by cruise ships that are sailing to/from Greenland, as well as winter cruise ship calls at the port network.

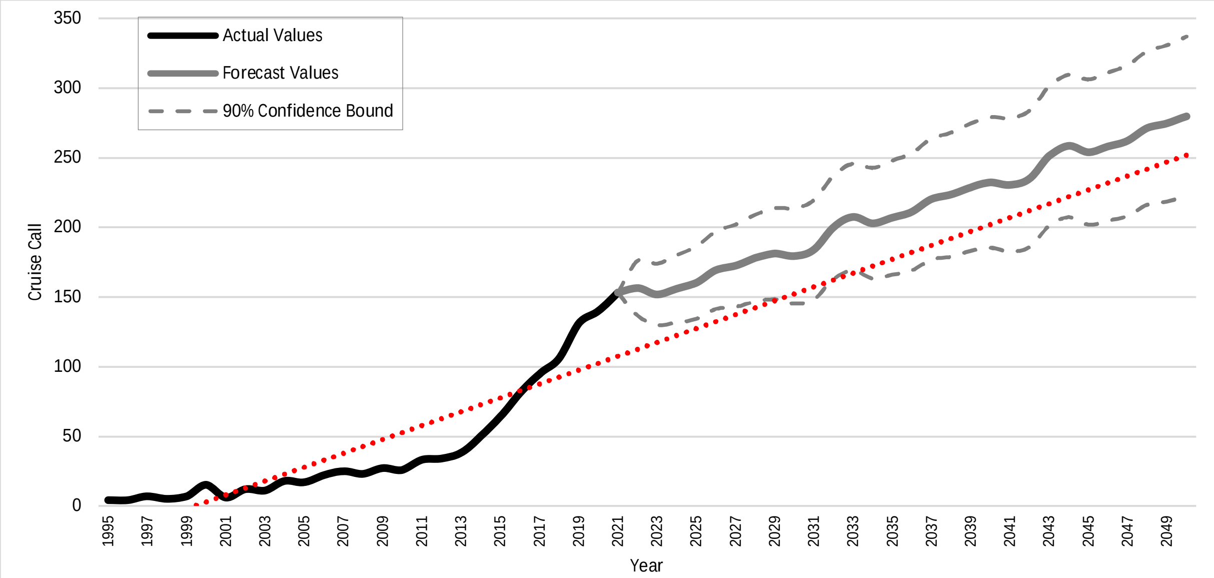

Figure 9. Historical and forecast of cruise ship call

However, port infrastructure restrictions have limited (relatively) large cruise ship calls. Furthermore, the rapid increase in the number of expedition and cruise ships raises the concern about safe disembarkment and embarkment and providing services to the passengers in the port network.

In this vein, (small) neighboring ports of call (e.g., the Ports of Isafjordur Network) can be complementary in offering services to cruise calls. This is because cruise ports can be complementary, rather than competitive, and a network of ports can be included in the same cruise line itinerary. Servicing the relatively small expedition and cruise vessels can be decentralized from the Port of Isafjordur to the smaller ports in the network. The optimal distribution and decentralization of cruise vessels can decrease the port traffic congestion in the Port of Isafjordur.

The network has been capitalizing on the factors that contribute to its competitive advantage to attract more cruise lines. The port network has continuously been upgrading to accommodate cruise ships and enhance the image of the port network (see Figure 5).

Marti pointed out the concepts of site and situation as the key contributing factors for the selection of a port call (Marti 1990). Site refers to physical factors, such as port infrastructure and superstructure, and situation refers to physical and cultural qualities. Marti distinguished three categories of cruise ports according to their operational characteristics and identified their respective key attributes for performing successfully. McCalla (1998) examined the factors affecting the attractiveness of a port to the cruise companies from the cruise ports' point of view.

There are attractive natural sites and towns around the Ports of Isafjordur Network that offer appealing expedition and cruise activities. The city's surrounding region is uniquely suited as a cruise and yachting destination and provides many forms of tourism. Furthermore, the port aesthetics such as leisure and culture, design and cognition, atmosphere, recreational facilities, and memory (Lu et al. 2020) positively have been influencing the port image and tourist satisfaction and loyalty.

The largest vessels that have called at the Port of Isafjordur are: 1- MSC Preziosa (LOA: 333.33 m, B: 37.92 m, D: 8.65 m) and MSC Meraviglia (LOA: 315.83 m, B: 43 m, D: 8.75 m). The current port development fulfills the requirement of these large ships. Therefore, the expected increase in cruise vessel calls and average sizes until 2050 can be serviced in the port network, using all four ports.

Concluding Remarks

Knowledge of future shipping trends is essential for any port, as the future number of vessel calls and their characteristics have implications for developing/adapting the port layers including infrastructure, operation, services.

This research project provides support for decision making to develop the port layer. The results can be used by the Port Authority for future port planning, design, and development to maximize their berth utilization, allocate port resources, alleviate congestion, manage traffic, mitigate emission greenhouse gases, enhance safety, and identify bottlenecks due to restrictions in the wet and dry areas of the port (Zhou et al., 2020).

The port traffic analysis was based on the prediction of port throughput in conjunction with the port infrastructure. To handle the increasing projected volume of containerized cargo, vessel capacity will continue to increase, and vessel sizes between 800-1200 TEU come into service by 2050. Even with this increase in vessel size, an increase in service frequency is expected. However, major industry events and trends could impact vessel services. Therefore, the port should be strategically planned and developed (Eskafi 2021). A balanced distribution of services across the week helps to avoid peak activity and thus increases the efficiency of the port (terminal) operation and maximizes throughput with limited port facilities.

The demand on quay length for cruise vessels is particularly important given the worldwide trend towards larger cruise ships and the increasing number of calls. The current development project at the Port of Isafjordur provides enough suitable infrastructure in the port (e.g., wet and dry areas) through the projection and accommodates the numbers and sizes of forecasted vessel deployments. Cruise call is expected to continue increasing. To accommodate the increasing number of cruise calls, servicing the relatively small expedition and cruise vessels can be distributed in the network by maximizing the use of the smaller ports (i.e., Sudureyri, Flateyri, Thingeyri).

Given the many uncertainties involved in the volatile market environment flexible port planning and development should be accounted for to accommodate different vessels with different sailing requirements in different layers. The results of this research project facilitate decision making for adaptive planning to develop a flexible port that accommodates a variety of vessels that utilize the economies of scale and thus maintain the competitive position of the Ports of Isafjordur Network.

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