CHALMERS

Scrutinizing the tradition

What are the economic implications of circumnavigating the African continent instead of using the Suez Canal?

Bachelor thesis for International Logistics Program

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DEPARTMENT OF MECHANICS AND MARITIME SCIENCES

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Cover:
The guided-missile destroyer USS Ching-Hoon escorts a Maersk container vessel in the Gulf of Aden, March 1, 2019. Photo by U.S. Navy Mass Communication Specialist 2nd Class Logan C. Kellums.

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PREFACE

Det sägs att historien har en tendens att upprepa sig själv. Vid två tidigare tillfällen har Suezkanalen, denna ytterst viktiga handelsled, blockerats. Första blockaden orsakades av en konflikt mellan Egypten och Israel som stängde av kanalen för passage mellan 1967–1975, och andra gången på grund av att fartyget Evergiven fastnade i en knapp vecka i Mars 2021. Den 20 november 2023 fick världen se bilder på hur Houthi-rebeller från Yemen kapade ett Israel-relaterat fartyg i Röda Havet. Återigen ställdes världshandeln på sin spets. De följande dagarna präglades av förvirring. Varken militären eller världens kommersiella handelsflotta visste hur man skulle agera. Cirka en månad senare hade attackerna eskalerat till den punkten att världens stora containerrederier ställde in rutten genom Röda Havet och Suezkanalen och i stället seglar runt Afrikas spets, Godahoppsudden. En samlad militärallians ledd av USA påbörjade ”Operation Prosperity Guardian” i hopp om att eskortera handelsfartyg genom kanalen och bibehålla denna vitala handelsådra. Attackerna slutade dock inte och fartyget fortsätter navigera runt Afrika. För att täcka för utökade operationella kostnader har linjerederierna infört en uppsjö olika extra-kostnader mot kunder. Utöver detta har marknadspriset för samtliga handelstrader ökat markant. Som studenter på Chalmers Internationell Logistik har författarna till rapporten valt att gräva djupare i de faktiska kostnaderna rederierna möter vid det nya handelsläget, samt simulera kostnaderna vid olika marknadslägen. Historien har en tendens att upprepa sig själv. Detta är troligen inte sista gången Suezkanalen är i en konfliktzon. Vi hoppas kunna ge insikt i ett problem som inte bara berör sjöfartsintresserade, utan även företag och privatpersoner. Modellerna presenterade i rapporten kommer ge rederier, köpare av sjöfrakt och kommande studenter inom sjöfart en möjlighet att reagera tidigt vid nästa tillfälle Suezkanalen blockeras. Denna rapport skrivs på det sista året av Internationell Logistik och berör 15 HP. Vi vill rikta ett stort tack till Sjösektionen, Chalmers fakulteten samt vår handledare tillika programansvarig Martin Larsson. Vi vill även passa på att tacka Nils Vinneby på Scanocean och Anders Korsgren på Svenska Skeppshypotek, som har hjälpt oss få fram korrekta parametrar, samt väglett oss till användbara kontaktpersoner inom studieområdet.

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SAMMANDRAG

Detta kandidatarbete, utfört vid Chalmers Tekniska Högskola, undersöker de ekonomiska konsekvenserna av att navigera runt den afrikanska kontinenten som ett alternativ till att använda Suezkanalen för containerfartyg under varierande marknadsförhållanden. Fallstudien motiverades av historiska avbrott av Suezkanalen, inklusive blockeringar och nyligen geopolitiska spänningar som tvingade handelsfartyg att omdirigera via Godahoppsudden. Forskningen analyserar de extra driftkostnader som uppstår från de alternativa rutterna och modellerar break-even-punkter under olika marknadsscenarier och utnyttjandegrad av lastkapacitet.

Genom kvantitativ analys, inklusive fallstudier och ekonomisk modellering, utforskar rapporten hur optimering av fartygsstorlek och val av rutt påverkar fartygens ekonomiska resultat. Resultaten visar att valet av rutt har en betydande ekonomisk inverkan. Inverkans signifikans varierar beroende på marknadsförhållanden och fartygens kapaciteter. Nyckelfynden indikerar att större fartyg drar större nytta av skalfördelar, vilket kan kompensera för de ökade kostnaderna som är förknippade med den längre seglingen runt Godahoppsudden, särskilt under höga marknadsförhållanden.

Studien begränsas till de ekonomiska aspekterna av att omdirigera ett fartyg från Fjärran Östern till Europas nordvästra kontinent. Den tar inte hänsyn till miljöpåverkan eller geopolitiska risker som är förknippade med ruterna. Dessutom fokuserar den enbart på containersegmentet inom sjöfarten och exkluderar andra typer av maritim transport. Dessa begränsningar föreslår områden för ytterligare forskning för att utveckla en mer omfattande förståelse av de bredare konsekvenserna av störningar i Suezkanalen på den globala sjölogistiken.

Nyckelord: Suez Canal, Economies of scale, Red Sea Surcharges, Container shipping, Cape of Good Hope

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ABSTRACT

This Bachelor thesis, conducted at Chalmers University of Technology, examines the economic implications for circumnavigating the African continental as an alternative to using the Suez Canal, for container vessels in varying market conditions. The case study was motivated by historical disruptions in the Suez Canal, including blockages and recent geopolitical tension that forced commercial vessels to reroute via the Cape of Good Hope. The research analyzes the additional operational cost incurred from the alternative routings and models the break-even points under different market scenarios and space utilization.

Through quantitative analysis, including case studies and economic modeling, the thesis explores how the vessel size optimization and route selections effect a vessel and subsequently the transport service provider's economic result. The findings indicate significant economic impact of route choice, which vary according to market conditions and ship capacities. Key findings indicate that larger vessels benefit more significantly from economies of scale, which can compensate the increased cost associated with the longer sailing around the Cape of Good Hope, particularly in a high market condition.

The study is limited to the economic aspects of rerouting a vessel from far east Asia to the northwest continent of Europe. It does not account for environmental impacts or geopolitical risks associated with the routes. Additionally, it focuses solely on the container shipping segment, excluding other types of maritime transport. These limitations suggest areas for further research to develop a more comprehensive understanding of the broader implications of Suez Canal disruptions on global shipping logistics.

Keywords: Suez Canal, Economies of scale, Red Sea Surcharges, Container Shipping, Cape of Good Hope

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ACRONYMS AND TERMINOLOGY

Acronym	Explanation
BAF	Bunker Adjustment Factor
CAC	Contingency Adjustment Charge
CAPEX	Capital Expenses
CC	Contingency Charge
CO2	Carbon Dioxide
COGH	Cape of Good Hope
COS	Contingency Operational Surcharge
DWT	Deadweight Ton
ECA	Emission Control Area
ECS	Emergency Contingency Surcharge
ES	Emergency Surcharge
FEA	Far-East Asia
FEU	Forty-Foot Equivalent Unit
HFO	Heavy Fuel Oil
IMDG	International Maritime Dangerous Goods
IMO	International Maritime Organization
MGO	Marine Gas Oil
OCC	Operational Continuity Charge
OPEX	Operational Expenses
ORC	Operational Recovery Charge
PCS	Port Canal Surcharge
PDA	Port Disbursement Account
RORO	Roll-On Roll-Off
RSS	Red Sea Surcharge
SCA	Suez Canal Authority
SCF	Suez Canal Fee
SCFI	Shanghai Container Freight Index
SCNT	Suez Canal Net Tonnage
SDR	Special Drawing Rights
SOFR	Secured Overnight Financing Rate
TEU	Twenty-Foot Equivalent Unit
THC	Terminal Handling Charge
USD	United States Dollar
VLSFO	Very Low Sulphur Fuel Oil
VOYEX	Voyage Expenses

1. INTRODUCTION

In an era marked by interconnected economies and the relentless pursuit of efficient global trade routes, maritime transportation plays a pivotal role in shaping international commerce. The Suez Canal stands as the backbone of trade, providing shortcuts that significantly reduce travel distances for vessels transiting between major trading regions (Wang & Meng, 2012).
However, as the world faces evolving geopolitical and economic landscapes, it becomes important to scrutinize the conventional strategies surrounding the canal. Now, more than ever, liner shipping companies face significant challenges with passing through the Suez.

Beginning in November 2023, the Houthi Rebels in Yemen started attacking commercial vessels passing the Bab-el-Mandeb strait on its way to or from the Red Sea and subsequently the Suez Canal (Scarr et al., 2024). To protect the lives of seafarers and the vessel itself, almost all the liner shipping companies have taken precautions. Either military convoys through the Red Sea or circumnavigating the Cape of Good hope. According to (Bose, 2024), this diversion is estimated to take an extra 10-14 days and increase operational spending.

Business Insider (Dzhanova, 2021) writes, this is not the first time the ships have diverted from the canal. In the wake of a conflict between Israel and Egypt, the canal was closed between 1967-1975, and in 2021 when the Evergreen operated "Ever Given" vessel got stuck, the canal was again rendered useless or posing too big of a risk to pass through.

Since the beginning of 2024, the liner shipping companies have introduced additional surcharges to cover for the increased costs, both operationally for the vessel itself, but also covering for the subsequent congestion in ports and empty container imbalance (Solsvik & Trompiz, 2023a).

This research paper explores the actual costs associated with circumnavigating the African continent, compared against the utilization of the Suez Canal. By delving into economic and logistical considerations, this study aims to unravel the complexities surrounding these navigation choices, what the economic impact they bear and what vessel utilization is needed to cover for the increase in costs.

1.1 Aim of the study

The aim of the report is to examine the cost and logistical difficulties surrounding circumnavigating the Suez Canal. This will later result in the optimal vessel size and capacity utilization in different market conditions to reach at least a break-even point compared to passing through the Suez Canal. Subsequently, the report will give a nuanced understanding of the trade-offs, valuable insight for the stakeholders, and highlight what the optimal utilization of maritime routes is. If a diversion around Cape of Good hope will be imminent in the future, we hope that this paper can be useful in understanding the difficult economic aspect of circumnavigating the canal, as well as providing a model for the required capacity utilization.

1.2 Research questions

“What are the actual extra costs of circumnavigating the Suez Canal around Cape of Good Hope in a liner shipping trade from far east Asia to the northwest European continent?”

“What is the vessel space utilization required to cover the cost in different market conditions?”

“What is the spot market rate required to cover the cost in different market conditions?”

“Can any economies of scale benefits be identified?”

“Are the additional Red Sea surcharges used to cover costs, or increase profits?“

1.3 Delimitations

The research is limited to include the economic considerations only. It is also delimited to analyze a certain trade pattern from Far East Asia to Northwest Europe, heading westbound. Numeric values and outputs are initially taken from 2023, with exception of cases where historical values play a pivotal role. The study is only examining the container shipping segment and is directed for container vessel sizes that operate on the determined trade. To limit the paper to relevant technical, geographical, and economical aspects, the following topics has been excluded:

- Environment concerns
- Risk management
- Different Routings - Only FEA - Europe (Shanghai - Rotterdam) westbound will be examined.
- Weather factor

Spot market price is the sole income source for the transport service provider. It’s possible that extra charges towards the customer are issued, for example to cover the THC cost, documentation handling etc. These rates are individually priced for each company; hence this paper will not include THC as an income, just as a cost item.

2. THEORY

The intricate dynamics in the container market can best be explained by mapping out what elements react to what outcomes. For instance, the spot market is directly linked to the income, and the speed is directly linked to the cost. But imagine if a vessel is sailing at a higher speed, the vessel will then be able to complete more trips, and subsequently make more money. In a nutshell, the container market is dynamic and requires the reader to thoroughly understand what elements affect each other. This chapter provides an insight into the vast dynamics of the container market, essential to understand this paper. It will explain how the reference paper is utilized to provide an understanding of the market and its outcomes. The chapter will also explain the following topics: Spot market/SCFI, contract rates vs. non contractual customers, sailing speed, load factor/vessel space utilization, supply chain resilience, bunker & the bunker market, routing, PDA, container cost, ship financing, Suez Canal cost, relevant shipping charges, economies of scale in container shipping. After this chapter, the reader should have extensive knowledge to understand the thesis, methodology and results.

2.1 Spot market / SCFI

For all non-contractual customers of sea freight, the spot market provides an insight into the prices of sea freight at a specific time. The most prominent spot market index is the Shanghai Container Freight Index (SCFI) which presents the spot market prices for container freight on 13 different shipping routes, although all of them originating in Shanghai. Founded in 2005 by the Chinese government, the indexes' primary purpose is to assist and give insight to traders of transport services by combining data of 15 different shipping routes (Yang, 2016). This data is gathered from 23 of the biggest liner shipping companies and 26 of the biggest freight forwarders in the world (Shixin, 2024). According to (Yang, 2016) the index also serves a secondary purpose. The index is open for derivative trades, which opens the possibility for financial institutions, companies, and private investors to trade on the index. Consequently, the index is a good way for traders to hedge for future downturns in the market, by shorting the index and making money on a worsened container shipping market. In theory, shipping companies can hedge for future container market volatility by investing either bullish or bearish on the index they themselves are a part of. This mitigates the risk for big volatilities of the shipping companies and will subsequently make them more attractive to investors interested in investment balance. Many transport service providers worry about the negative implications of an open derivatives market. Some carriers are worried the index will be prone to speculations and overlook the actual primary purpose of the index; to act as a benchmark. According to the Shanghai Shipping Exchange (Shixin, 2024),the SCFI represents the current rates for a general dry cargo TEU. This meaning the index provides a price for a standard twenty-foot-long container with no special equipment inside like temperature control units etc. The index also incorporates relevant surcharges like bunker adjustment factor (BAF), Peak Season Surcharge (PSS), Port Congestion Surcharge (PCS) and Suez Canal Fee (SCF).

The spot market price is directly linked to the income of the liner shipping company. It serves as an indicator for their contractual rates as well as their non-contractual rates (Woods, 2018a). According to (Stopford, 2009a) the transportation cost i.e., spot market price for consumer and the freight revenue (i.e., spot market price for liner shipping companies) can both be accredited to the phenomenon of demand and supply. If demand is low and supply is high, the spot market is low. The same goes for the reverse scenario of a high demand and low supply, the sport market will then be high.

2.2 Contract rates vs. non contractual customers

A contractual rate is a predetermined rate negotiated between the transport service provider and the transport service buyer. Included in the contract is also a commitment level from the buyer, specifying the amount of, in this case containers, the customer will ship with the transport service provider during the contract period. There are several benefits for each party to have a contract. The service provider gets an income guarantee and enables space forecasting, also called allocation, on their vessels. For the service buyer, they get a stable supplier of transports and often a lower cost than the juxta positioned spot market rate. For the sake of simplicity, one can view the contract rates as a discount on the spot market price. Depending on the transport providers forecast of the spot market, they can offer different contract rates depending on preferred contract validity. If the service provider believes the spot market will increase in half a year, a validity of six months will offer lower rates than one with twelve months validity. It's a possibility that the customer has a different outlook on the spot market and might very well be able to hedge for higher spot prices in the future (Woods, 2018b).

As mentioned previously, the spot market is dependent on relevant costs for the container market. A transport provider does not want to offer a contractual rate that is too low for the relevant spot price. That will result in lower income and higher costs. The contractual rates are determined during the procurement period. A common practice is for a transport service buyer to reach out to large liner shipping companies during the procurement period to receive offers. If the customer offers a substantial volume, their bargaining power will be large, and the liner shipping companies will do their best to win the volumes. Once the procurement period ends, the transport buyer will present their nominations (Woods, 2018b). The main differences between contractual rates and non-contractual rates are therefore the uncertainty in volumes and difference in rates. Another difference is also the benefit of guaranteed space on vessels if the transport buyer is a contractual customer. Because the transport service provider is nominated to a certain volume, they can estimate the demand for transport from this specific contractual customer and allocate space on their vessels for these (Bhonsale, 2023).

2.3 Speed

The sailing speed of a container vessel plays a significant role in determining the vessels total day-to-day cost, also known as operating cost (OPEX). Sailing speed for container ships vary in the market dynamic (Wang & Meng, 2012). An assumption for this report is that in a low market dynamic, a container vessel operates in an average speed of 18 knot, while in a medium-high market, container vessel operates on an average speed of 20-22 knots. The speed variation as a metric has a significant impact on two major parameters presented in the calculation; operating days and bunker consumption in the results published in this paper.

In 2007, Maersk (then Maersk Line) initiated a trial consisting of 110 vessels sailing at lower than design speed. A ships design speed is the speed the hull and machinery are intended to run on for long periods at a time. The Maersk trial in 2007 decreased the engine power to a minimum of 10%. In practice, this meant the ship sailed at about half of the design speed. This can be explained by the nonlinear relation between engine output and speed. When Maersk tried a similar experiment for their Triple-E class sailing at 18 knots instead of the industry norm of 22-25 knots, they experienced 20% reduction in CO_2 emissions per container carried (Psaraftis & Kontovas, 2013) .

Decreased CO_2 emissions and decreased bunker consumption are the main features making slow steaming popular today. But this speed practice also comes with various tradeoffs according to (Psaraftis & Kontovas, 2013). One example of a tradeoff is the decrease in customers served. For example, Shanghai – Antwerp takes 35 days at 18kn when sailing around Cape of Good Hope compared to 27,5 days for the same distance at 23kn. In a high market with lots of cargo volumes flowing, a container vessel wants to maximize the number of customers served and loaded containers. Sailing at a higher speed to serve more customers and subsequently more customer might in some spot market environments outweigh the increased cost of bunker. Another tradeoff with adjusting sailing speed is the imbalance in ports. A container shipping company runs on a tight schedule with predetermined port calls. If the vessel in a certain scenario decides to adjust the sailing speed to account for change in spot or bunker market conditions, the next port call schedule will be skewed, exposing the vessel to waiting time in port. The ports capacity limitations might lead to the vessel having to anchor outside the port and wait for an available slot. An exporting customer at the specific port can also face problems with cut off times. A cut-off time is a predetermined time in which the container must be available in port for loading on a vessel (Woods, 2018b). If the vessel sails too fast and calls port before the cargo is ready to be exported by the customer, they will miss the opportunity to load on this vessel and must wait for the next one. A good balance between serving as much customers as possible, and timing port calls and decreasing bunker costs and emissions are therefore important for a shipping company to manage.

2.4 Load factor / Vessel space utilization

A container vessel consists of tiers, bays, and rows to facilitate containers both on deck and under the hold. Using a cartesian coordinates in a 3D model one can describe the loading spaces as tiers being the height (z-axis), rows being the length (y-axis) and bays being the width (x-axis). The aim of every container vessel is to utilize as much of the free space as possible. A 100% load factor means that every available container slot is occupied whilst a 50% load factor means that half of every container slot is occupied (Stopford, 2009a). Having a load factor of 100% might in principle look good and provide vast amounts of revenue for the container shipping company, but there are tradeoffs to this high-capacity utilization. If a container vessel is fully loaded with 18.000 TEU containers, all having max cargo weight of 25 tons and the container itself weights 2,5 tons, the vessel will carry an equivalent of 330.000 normal sized European cars. With a ship being 400 meters in length, this means 825 cars stacked on each other per meter in length (International Council on Clean Transports, 2022). The immense weight a vessel with 100% load factor carries consequently makes the draught of the vessel increase. According to (Rodrigue, 2020) an 18.000 TEU vessel (referred to the Tripe E Maersk class) has a draught of 14,5 meters. With the worlds mean draught being 14 meters (Notteboom et al., 2021), meticulously planning the cargo on board becomes vital. Another factor to consider when planning the cargo capacity is the load and offload sequence. Every lift of a container in port takes time and costs money. According to (Stopford, 2009a) a container lift in port costs 220 USD as of 2009, a number most likely larger as the writing of this paper. If a container is destined for a port in the middle of a route, ex. Singapore in a westbound journey from Far East to Europe, is positioned with several containers on top, these extra containers need to unload from the vessel, resulting in a cascade of container movement costs. A high load factor will consequently increase the risk of these extra costs.

The load planning becomes even more intricate once reefer containers and dangerous goods containers needs to be planned. Reefer containers are temperature-controlled transport units which needs undisrupted access to auxiliary power to function. A container vessel has limited access to these power sockets onboard, hence planning of positioning becomes even more important. Dangerous goods containers are in principle a container loaded with a dangerous goods substance classified under the IMDG code. The code can demand certain positioning of the container on the ship to prevent the cargo from damaging itself, other loaded units or the crew, and ultimately the vessel. The aim of every liner shipping company is to have as high load factor as possible. According to (Stopford, 2009) the load factor is also a sign of economies of scale. Having a high load factor will provide scale benefits. One can also argue that the load factor is linked to the spot market and the demand for transport. As previously mentioned, the spot market prices follow the supply and demand principles. If the demand is high and supply low, the load factor will subsequently be higher. In the results of this paper, the calculations and financial results depend heavily on the load factor.

2.5 Supply chain resilience

Liner shipping is defined by (Stopford, 2009b) as "… ships that operate on a regular scheduled service between ports…". Since the ports and route is predetermined, the liner shipping companies can accurately estimate the time of departure and arrival. This is important to administrate surrounding logistics like inland and intermodal transports as well as customs declarations. A minor disruption like mechanical failure or weather factors can cause disruptions all along the supply chain. A larger magnitude disruption, like war, terrorist actions or in the case of this paper, the circumnavigation of the Suez Canal to protect the life of seafarers and the assets of liner shipping companies, the effects can be proportionally larger. A container ship that sits idle in the Suez Canal for more than 10 days should according to (Wu & Xu, 2021) consider rerouting and deviate south of the Cape of Good Hope. The distance difference between navigating through the Suez Canal and navigating the Cape of Good Hope is roughly 3300 nm, which at 20 knots will be travelled in 165 hours, just short of seven days. A disruption of this magnitude will likely affect all ports included, with schedules skewed, containers waiting for pickup and/or delivery and empty container positioning. According to (Miller-Hooks et al., 2011), the effects of a disruption can be reduced if the response is swift and within an acceptable budget, hence rendering the supply chain resilient.

2.6 Bunker & the bunker market

Bunker is the compassing term for the ship fuels used in various shipping industries. Unlike fuels used on land in small engines, shipping fuels are consumed in enormous quantities by huge engines propelling thousands of metric tons of steel. Shipping has naturally evolved from man and wind power to coal and steam and ultimately to complicated combustions of fuels. In the early days of combustion engines in shipping, heavy fuel oil (HFO) was the primary energy source (Endresen et al., 2007a). The low cost and next to no emissions regulations made HFO popular for the whole shipping industry (Endresen et al., 2007b). One of the key metrics when comparing fuels is the energy density. According to DNV (Anders, 2019), this metric determines how much fuel needs to be combusted to reach certain energy output measured in MJ. The metric can be divided into two categories; volumetric and gravimetric where the former measures the space the fuel occupies and the latter the actual weight of set amount of fuel. For a shipping company aiming to optimize bunker expenditures and emissions, these metrics becomes vital.

The shipping company wants to maximize the space available to load containers on to increase income, hence choosing a fuel with low volumetric density, but at the same time use a fuel with low gravimetric density to not weigh too much and subsequently increasing draught and fuel consumption. The bunker market consists of a variety of bunker fluids with different important metrics to consider like price, energy density and emissions. According to (IEA, 2019), the bunker fuel demand has risen over the last six years and for the first time since 2020, the low Sulphur variant of HFO, called VLSFO now exceeds HFO (VLSFO is mentioned as MGO in the source as well as in this paper) on a yearly basis. One reason for the shift in demand might be explained by the IMO Sulphur regulations put in place in 2020 (IMO, 2021), aiming to limit the Sulphur content in marine fuels to 0,5%, far lower than previously 3,5%.

Shipping companies cannot control the bunker market, but they can control the consumption of their fleet. The main fuel used for shipping in 2015 is according to (Balcombe et al., 2018) HFO which represents 72% of all fuels consumed. This fuel is produced from the leftovers from the process of crude oil refining (Uhler et al., 2016). This means that the supply of bunker fluids is heavily dependent on the standard oil refining processes, price, and demand. The container shipping industry are, unlike from the SCFI, not the only ones using this market. The demand for bunker fluids is derived from all shipping sectors, like bulk, tanker, and RORO. It is therefore hard to distinguish the container sector's role in the price of bunker, making it even more intricate than the spot market. The supply of bunker fluids can be artificially manipulated by measures like tariffs and trade barriers. One of these examples were the sanctions on Russia immediately after the invasion of Ukraine (European Council, 2024). When the sanctions on Russian oil and gas was introduced, the supply of oil was decreased, but the demand remained largely the same. This in effect means that the price of bunker fluids increased significantly.

2.7 Routing

Most containerized goods on the Asia-European trade initially passes through the Suez Canal to reach its destinations with minimized lead time. However, there are three possible routes to consider on this trade route. In addition to transiting the Suez Canal, vessels can either travel eastbound from Asia through the Panama Canal, or westbound, bypassing the Cape of Good Hope (Vuki´cvuki´c & Del Mar Cerbán, 2022). Even though there are 3 separate ways to consider, there are only two adequate routes to examine – the transit through the Suez Canal, or its substitute route around the Cape of Good Hope. Both routes are subject to passages through emission control areas (ECA), put in place by IMO. According to (Vuki´cvuki´c & Del Mar Cerbán, 2022), vessels are regulated to stricter reductions of emissions in ECA areas, and therefore need to operate on other fuels than heavy fuel oil (HFO). These alternative fuels entail additional economic costs, consequently influencing the choice of routing for the vessel. This paper will examine the economic performance and difference of operating a vessel in the two respective routings. The decision in routing is not an outcome from the high-medium-low market which is explained under the 2.1 paragraph. Instead, the alternative routing around Cape of Good Hope is only based on a closure or implication of transiting the Suez Canal or red sea area. However, according to (Nightingale & Diakun, 2024), the re-routing completely changes the trade pattern, which can be a result of fluctuation in the spot market.

2.8 PDA

PDA is an abbreviation of "Port Disbursement Account". One can compare it to a specialized bank account with a standing balance to accommodate the costs a port call will bring. Some of the costs usually covered by the PDA are customs clearance, transports, storage, and terminal handling. The main reasoning behind a PDA is to ease the administration strain on the transport service provider. A large transporter might have hundreds of ships operating simultaneously with several port calls each day. The costs associated with a port call will often be predetermined in a contract between the transport provider and the port management. Some of the largest transport service firms have subsidiary firms specialized in port operations, like Maersk's APMT, MSC's MEDLOG, CMA CGM's CEVA and COSCO's CSP (Lloyds List, 2023). Martin Stopford claims in his book Maritime Economics 3d edition that there are about 400 ports in the world, but the top 60 handle up to 98% of the goods (Stopford, 2009a). The reference paper uses PDA information gathered from COSCO in 2019, but only for an 18.000 TEU vessel. With a linear regression model this paper can conclude the PDA costs for all ship sizes compared in the result.

2.9 Container cost

The container costs have an initial production cost, a depreciation cost and operational cost. For this paper, the initial production and depreciation cost will not be included, but the operational cost will be. The number of containers in movement per company can be estimated, but the estimation will be prone to errors and uncertainty. The initial production cost is also widely unknown as well as the economic lifespan. Because of this, only the operational costs will be included. According to (Stopford, 2009a), the daily cost per TEU is 0,7 USD and maintenance cost per voyage is 50 USD. Since the calculations in this paper focuses solely on one trip, and not a round voyage, the maintenance cost is halved. The maintenance of a container can be patching holes, corrosion prevention measures and repainting. During the lifespan of a container, it's exposed to weather, pressure, and lifts. The construction and handling of a container is heavily regulated in IMO: s International Convention for Safe Containers (International Maritime Organization, 2014). The container fleet is a quintessential part of a transport service providers assets. An empty container will not generate money unless the cargo space is bought or occupied by a transport service buyer.

2.10 Ship financing

When investing in a new vessel, shipping companies need to finance the construction of a newbuild. The process of purchasing a new vessel involves many steps and parties and are usually a complex procedure. However, there are primarily two financial options to consider when investing in a new vessel. A shipping company can either finance the newbuild with equity capital, obtained from shares or earnings. The other, most common option is to finance it through banks and other creditors (Gostomski & Nowosielski, 2020).These parties earn their stake from the investment by collecting interest rates from money lent to the shipping company. The interest rates fluctuate based on the market dynamics and the relation of the shipping company and the bank/other creditors. However, according to recent information received from Svenska Skeppshypotek (A.Korsgren, personal communication, February 19, 2024), they claim that the last two years, financiers have used then American Secured Overnight Financing Rate Data (SOFR) as a reference rate in ship finance. The SOFR is a percentual measurement of the expenses associated with borrowing cash overnight, backed by treasury securities (Federal Reserve Bank of New York, 2024). The SOFR have grown from 0,05% in beginning of 2022 to 5,30% in the beginning of 2024. Above this reference rate, there is a margin of 2% to 4% to apply, which gives an approximate value of 7,5% to 9,5% in February 2024, according to A.Korsgren at Svenska Skeppshypotek. The sum of investment for the container vessel sizes (18,000 TEU to 25,000 TEU) used in the paper, estimates to range between approximately 153 to 206 MUSD (Ge et al., 2021). An assumption that 100% of the vessel is financed by loan to make a better view of financial costs. Even though there might be cash finances, 7.5% will be calculated on total ship build price.

2.11 Suez Canal cost

The canal is operated by the Suez Canal Authority, a branch of the Egyptian authorities. The upkeep of the canal is funded by the canal fee that is charged for every vessel that transits the canal. The fee structure upheld by the SCA is based on two different variables, the Suez Canal net ton, and Special Drawing Rights (SDR). Martin Stopford (Stopford, 2009a) describes the net ton charge as a measurement founded by the SCA which prices the toll on a ship's revenue-earning capacity. The charge shares characteristics with the net tonnage of a vessel, i.e., the cargo carrying space below deck. The Suez Canal net ton charge is determined in advance by the classification society linked to the specific vessel. The classification society issues a certificate which is used to determine this specific charge. For a vessel without this certificate, the SCA adds gross and net tonnage together, to then divide by 2 and add 10% overhead. To decrease the risk of currency exchange losses, the SCA calculates the charge based on SDR: s which in turn can be converted to USD. Unlike the flat rate of transiting the Panama Canal, the Suez Canal cost is harder to calculate. For this paper, an online calculator built and operated by the SCA has been utilized. According to Reuters (Elimam & Abdallah, 2023), the canal authorities reported revenues of 9,4 billion USD during June 2022 – June 2023. The report also announces the total traffic in the canal, amassing a record 25 887 ships during the same period. Subsequently, the average charge per ship is roughly 360.000 USD.

2.12 Relevant shipping charges

In the wake of the attacks on the ships in mid-December 2023, the shipping companies introduced several extra surcharges to cope with the increased costs of circumnavigating the Suez Canal and to hedge for future congestions in ports (Solsvik & Trompiz, 2023b). The surcharges came with several different names and values but would nonetheless affect the transport service buyers' transportations costs. Amongst the big shipping companies, Maersk introduced charges amassing to 200 USD/TEU for the Far East – North Europe route (excluding PSS), CMA CGM announced 325 USD/TEU and MSC announced 500 USD/TEU. Among with these charges, many liner shipping companies also reinstated PSS, a charge previously used during immense demand peaks for shipping from Asia. The Peak Season Surcharge is usually applied between June and October each year as a tariff surcharge for both contractual and non-contractual customers. A normal PSS stretches from 150-300 USD per TEU but can in some instances reach far more than this (Xeneta, 2024). For example, the initial surcharges introduced by Maersk had PSS included, making their initial price for a twenty-foot container from Asia to North Europe cost an additional 700 USD (200 + PSS of 500). The initial charges aimed at reducing the economic impact the liner shipping companies had to face to circumnavigate the Suez Canal came in various abbreviations, making it difficult for a transportation buyer to identify what charges belongs to what. For example, Maersk calls their charges ECS, an abbreviation for Emergency Contingency Surcharge, whilst MSC calls it CAC, short for Contingency Adjustment Surcharge. Below are some charges introduced shortly after the attacks began.

Company name of container carrier	Charge acronym	Charge per TEU
Hapag Lloyd	ORC	$ 500
CMA CGM	CC	$ 325
HMM	OCC	$ 500
MSC	CAC	$ 500
Yang Ming	COS	$ 450
Maersk	ECS + PSS	$ 700
One	ES	$ 1 000
COSCO	PSS	$ 750

Table 1: Red Sea Surcharges applied per major container carrier. Charge acronyms differ, but the charge is attended for the same purpose. Sourced from the corresponding carrier website. Values as per initiation of December 2023.

Many of the above charges has since been reduced, albeit not removed. The current Houthi red sea problem is still a developing situation with no concrete solution in sight.

Another relevant shipping charge is terminal handling charges (THC), which occur from cargo handling and the operation of loading and unloading containers from the vessel onto the port. THC is an independent surcharge at either the origin or at destination and can vary based on the country or between ports. It is usually paid in local currency but will be converted to USD in this paper (Stopford, 2009b). THC is an expensive and critical charge in relation to other surcharges and could make or break a deal with involved customers. As previously stated, large vessel operators invest in port terminals like Maersk's APMT, MSC's MEDLOG, CMA CGM's CEVA and COSCO's CSP (Lloyds List, 2023) to be able to control the operation and the costs as well as to offer a competitive ocean freight. In this study, an approximate estimation of THC cost was carried out by comparing the cost between the major shipping lines. The analysis revealed a total cost of 344 USD per TEU.

2.13 Economies of scale in container shipping

This economic phenomenon can best be described by the economic benefits of large volumes. Just like a consumer would get a bigger price per standard unit (ex.kgs) when buying many units or a bigger package, so will liner shipping companies with larger vessels. According to (Rodrigue, 2020), historically, container ships have gotten bigger and bigger for each decade. In the beginning of the container era, vessel sizes were comparably tiny. Vessels ranged from 500-800 TEU but had a steady increase in size over the years to come. The 1970's saw the biggest capacity percentual increase of roughly 300% and introduced the 2.500 TEU vessel. This upwards trend continued along the years, but the world had to wait until 2005 to see the first vessel with over 10.000 TEU capacity. But in just 20 years, this feat was beaten by the introduction of today's largest vessels just above 24.000 TEU.

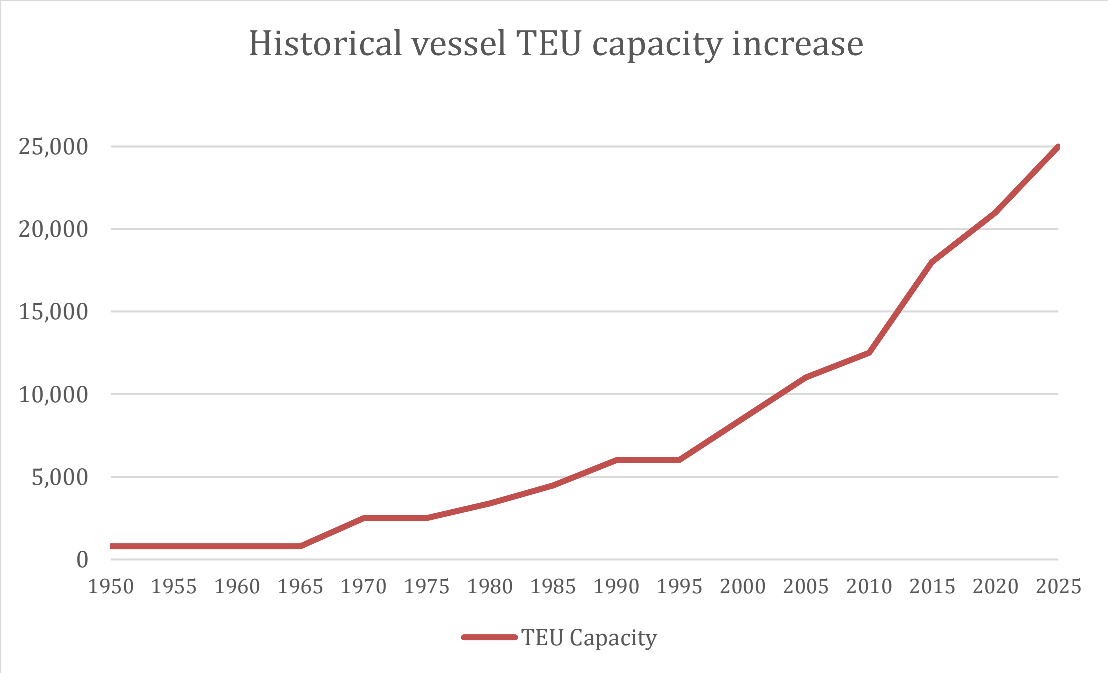

Figure 1: Container vessel size in TEU capacity from year 1950 - 2025.

Liner shipping companies are consistently competing in having the biggest ship and subsequently making the most profits. But it's not as simple as that. With a big ship also comes big restraints. First is the space constraint in the dockyards where the ship is being built. Far from all dockyards in the world have the capacity or knowledge of building these huge ships, leaving just a handful dockyards available. Since the liner shipping companies' constant race to get bigger, these dockyards are often full and the waiting time from blueprint to the ship being operational can take many years, not only in construction time but also waiting. Another factor to consider is the vessel size limitations in ports. As presented in section 2.4, the draught of a vessel is dependent on the total weight of the loaded containers. A 25.000 TEU vessel has roughly 40% bigger load capacity than an 18.000 TEU vessel, making it in theory 40% heavier fully loaded, excluding extra bunker fluids, hull, and machinery. The extra draught makes it impossible to berth fully loaded in many of the world's ports, making the vessel geographically limited. With extra load capacity also comes extra width. The Emma Maersk (IMO 9321483) of 18.000 TEU is according to Marine Traffic (Marine Traffic AIS Data, 2024) roughly 56,5 m wide, and the MSC Irina (IMO 9929429) with its 24.350 TEU is according to (Marine Traffic AIS Data, 2024), 61,3 m wide. The extra 4,8 meters in width can further exaggerate the vessels geographical limitation since cranes might not be able to reach the containers loaded on the vessel side opposite of the quay. The historical increase in vessel sizes is not for nothing though. According to (Cullinane & Khanna, 2000)**,** if a liner shipping company invests in a large ship the profits in a medium and high market will be significant, as shown in the results-section.

3. METHODS

The method chapter has been divided into subsections, allowing the reader to fully understand the structure of work and research. The case study is presented as a research method as well as the strategy behind case design, data collection, data analysis, and reporting of data.

3.1 Case study and its design

Since a large portion of this report refers to the reference paper, the methodology of a case study has been carried out. The case study as a research method is used to understand a real-life phenomenon in depth for a certain condition. It can be describes as finding a general response from examining a specific case (Yin, 2009a). To understand this, the study should inquire technical solutions in which multiple sources of variables can be used together with prior development of data studies to form a single result. In this case, the prior data development mirrors the reference paper that is used along the study. And the multiple variable sources are stated as the cost categories, voyage data and general assumptions. According to (Yin, 2009a), the strategy behind examination of such case includes the four phases of design, data collection, analysis, and reporting.

3.1.1 Designing the case study – Identifying and establish the logic of the case

The starting point of the design phase includes defining a relevant research question (Yin, 2009b). The study's research questions, and its objectives were defined after researching the subject of this case. The focus area of subject research eventuated in economies of scale in liner shipping, which resulted in the research question. This phase also involved selecting cases to be studied and determining the data collection and analysis techniques. Data collections were solely gathered from sources. No interviews were conducted. The case in which this study origins from are referred to as the reference paper and are stated in section 3.2. The reference paper uses regression analysis as a tool which partly became the main technique to generate data for this study. A regression analysis is based on an estimate of relationships between variables and have been used in the case study to identify data missing for certain parameters.

3.1.2 Data Collection – collect case study evidence

Data collection in case study research are usually detailed and extensive to gather as much information as possible about the case and its context. Since the results are largely dependent on the previous research provided in the reference paper, beginning with collecting data proved successful. The data in the reference paper provides parameters, but a portion of the values needed to be updated to the latest reference. Some of these are time-dependent parameters like spot rates and bunker price for a given time. Since this paper explores the costs associated with circumnavigating the Suez Canal and rounding the Cape of Good Hope, the distances provided also needed to be redefined. The given parameters did not fit entirely into this papers purpose and questions needed to be answered. The reference paper explores the limit to the benefits associated with economies of scale, in other words were the key variables the size of the vessels. This research on the contrary explores the economic impacts in different economic environments, but for the same vessel sizes as the reference paper. Consequently, the most important variables for this research became the income and costs associated with these specific time periods, although combined with the vessel sizes. To retrieve a relevant outcome from the quantitative data, every parameter has been counter checked with various sources from databases, analytic tools, and industry specialists.

3.1.3 General assumptions

Once data was gathered the paper explores the assumptions necessary. The primal assumption was the sailing speed in each market economic condition. As covered in the theory section, speed has an incremental effect on several large cost categories, like consumption and depreciation per trip. To be able to accurately predict these cost categories, an assumption of speed had to be done. Since a good market condition is more profitable, a logical solution was found to slightly increase the sailing speed once the market condition got better in the model. This was, vessels could complete more journeys and subsequently earn more revenue since the spot market income and costs associated to increased sailing speed do not increase nor correlate at the same rate. Another significant assumption needed to be concluded was the load factor. The load factor only effects the income, and slightly the operational costs of containers. The assumption of increased load factor once market conditions increase was made. This correlates to the basic principle of supply and demand. Although one might argue that a high demand might result in more vessels available, this assumption does not reconcile this to the degree of where it might influence the result greatly. The assumption can be explained by the fact that a good market condition, i.e., increased purchasing power from the transport service buyer, will lead to a higher load factor on the vessels.

3.1.4 Analysis

The analysis phase involves examining and categorization the dataset to address the purpose of the data. The datasets were categorized into sailing parameters, income parameters, and cost parameters, where subgroups of capital expenses, operating expenses and voyage expenses were applied to the cost parameters. Once the large datasets were in place and assumptions were made, the basic principle of methodology needed to be assessed. The paper is written with the positivist philosophy. Since the papers foundation is built upon actual numbers and figures, this choice was natural. No interviews were conducted, eliminating the need for interpretations, and further proving the papers' philosophy. The data were collected and observed, and afterwards conclusions and assumptions were taken. This research type is called inductive and were deemed the best fit for this specific research method. The information gathered for the data models were solely qualitative from a variety of sources. Additionally, the data collection method has a longitudinal timeline. Some of the data, for example the important information of spot rates and bunker price were taken from historical data provided by industry specific instrument and indices.

According to (Yin, 2009a) one of four, and the most preferred tool for analysis of a case, includes relying on and following a theoretical proposition that led to the case study and its research question. The objective of the proposition in this case study originates from the reference paper and have shaped the analytic strategies by implementing a regression analysis and relied on common principals as a methodology to analyze the collected data. Even though a methodology chapter was nonexistent for the reference paper, there was clear evidence of how this case could adapt data analysis methods from the reference paper.

3.1.5 Reporting

The final strategy behind examining a case is the reporting phase (Yin, 2009b). This involves reporting findings from the conducted calculations, crafting a narrative to convoy relevancy in the result, and detail findings and conclusions from the case. The reported findings were retrieved from calculations made from datasets addressed from the analysis. Since the size of datasets were large, a narrative had to be created to reflect on relevant findings. The narrative was boiled down to an economic base to be able to identify which parameters from the dataset that had an extensive effect on the result. This tended to be a mix between cost and sailing parameters. When significant parameters were identified, a set of findings and conclusion could be made from all calculations. Reported findings were presented in the result chapter to later be discussed in the discussion chapter.

3.2 Reference paper & Stopford 3rd edition of Maritime Economics

The quantitative calculations were built from recent research of a study made to review the effects from scale increase in vessel size in container shipping. The research is an economic analysis of ultra-large containership sizes under different market and operation conditions (Ge et al., 2021). The reference paper was used as a tool to build certain models and point out relevant parameters. In association with this numerical model, a building block of parameters sourced from the 3rd edition of Maritime Economics are used to analyze relevancy of the reference paper and gather additional parameters for considerations. The paper provided calculations to compute the actual costs of running a ship from a fictive origin to a fictive destination. Since the publication of the paper, the liner shipping trade has taken a turn. At the time of writing this paper, a vast number of ships are diverted around the Cape of Good hope. It is this papers job to answer, with reference and data models from the reference paper, what the actual costs are for this circumnavigation.

3.3 General assumptions and data collection

The study focuses on analyzing vessels with a capacity ranging from 18,000 to 25,000 TEUs, as they primarily operate in the vessel category of handling the Asia-Europe trade. Information about data presented below are in the data category of assumptions and data collection that has been present to the result of each assumption and from which source its origins from.

Assumption	Result	Source
Average sailing speed - low market	18 kn	Estimate
Average sailing speed – medium market	20 kn	Estimate
Average sailing speed – high market	22 kn	Estimate
Port calls & canal days Suez Canal	Singapore (1), Suez Canal (1)	Major liner shipping route schedules
Port calls & canal days COGH	Singapore (1)	Major liner shipping route schedules
Load factor – low market	60%	Assumed from basic supply/demand model
Load factor – medium market	70%	
Load factor – high market	90%	
Wage increases from 2007	30%	Stopford page 565

Data Collection	Data Result	Source
Operating time in a year (days)	360 days	Reference paper (Ge et al., 2021)
Spot rate - low market	800 USD/ TEU	SCFI June 2018
Spot rate – medium market	1000 USD/ TEU	SCFI July 2020
Spot rate – high market	1200 USD/ TEU	SCFI August 2020
Total non-ECA distance (Suez)	10541 nm	Veson Nautical
Total non-ECA distance (COGH)	13834 nm	Veson Nautical
Total ECA distance (Brest – Antwerp)	457 nm	Veson Nautical
HFO price - low market	450	Bunkerspot.com gathered through ScanOcean
HFO price - medium market	270	
HFO price - high market	275	
MGO price - low market	663	
MGO price - medium market	386	
MGO price - high market	344	
Terminal Handling cost	344 USD/TEU	Maersk
Ship newbuilding price	153 700 000 - 206 400 000 USD	Reference paper gives numbers for 18,20 & 25k TEU sizes. Linear regression model gives remaining numbers.

Depreciation	25 years	Reference paper (Ge et al., 2021)
HFO consumption (daily)	120 - 149 mt/day	Reference paper (Ge et al., 2021)
MGO consumption (daily)	120 - 149 mt/day	Reference paper (Ge et al., 2021)
Operating cost per day	1 USD/TEU	United States Merchant Marine Academy “Economies of Scale in Container Ship Costs” Midshipman William Murray
Interest rate February 2024	7,50%	Data from Svenska Skeppshypotek.
Suez Canal Cost	703 562 - 835 065 USD	Ship DWT information from internet sources put into Suez Canal authority’s own calculator tool. See more info below.

Table 2: Left column shows the parameter or assumption used or made. The mid column shows the numerical value gathered from the source or estimation on the right-hand column.

3.4 Suez Canal cost

SCNT is a specific measurement established by the canal authorities to measure net tonnage of a ship. It's calculated to be roughly half the deadweight, but to make room for errors in the report, we've concluded that the SCNT shall be 60% of the DWT. DWT has been calculated from three given statistics from ship sizes 18000, 19000 & 24000 TEU. The mean value between ship size and DWT has been identified as 10.006, a number used to calculate the increase in DWT to assume the DWT for the imaginary 25.000 TEU vessel. Total cost is calculated using Suez Canal authority's own calculator and includes the following:

Ship size (TEU)	DWT (mt)	SCNT (mt)	Grand Total (USD)
18 000	196 000	117 600	$ 703 562
19 000	197 300	118 380	$ 706 786
20 000	199 629	119 777	$ 712 561
21 000	199 855	119 913	$ 713 123
22 000	210 553	126 332	$ 739 065
23 000	221 251	132 751	$ 765 000
24 000	241 960	145 176	$ 815 200
25 000	250 155	150 093	$ 835 065

Table 3: The table represents the cost for the passage through the Suez Canal with metrics calculated based on each vessel size and their respective DWT. Currency is USD as per 2024.

3.5 Model building

To this day, there are no container vessels to reach a capacity of 25,000 TEU. Therefore, a regression model is applied on the actual parameters from existing vessels of 18,000-24,000 TEU to calculate a realistic result for a 25,000 TEU vessel. A regression analysis is based on an estimate of relationships between variables and have been used in the case study to identify data missing for certain parameters. The model building process presents calculations from sailing parameters and cost parameters for each vessel size, spot market and the two different routings alternatives.

3.5.1 Sailing Parameters

The sailing parameters required to calculate further cost parameters were total trip time (N), average sailing speed (v), number of trips per year (360/N), load factor (ωl), and total transported TEU per trip (ωL). Total trip time were calculated by summarizing sailing time in non-ECA zone (t) with sailing time in ECA zone (te) together with port & canal time (tp). The amount of crew (CRW) was also included in sailing parameters and its value were based on the vessel size (xTEU). A larger vessel size gave a larger amount of crew. Average sailing speed (v) and load factor (ωl) were given values which fluctuate based on the market position (low spot market: v=18 knots, ωL = 60%, medium spot market: v=20 knots, ωL = 70%, high spot market: v=22 knots, ωL = 90%).

The total trip time (N)

$$N = t + te + tp$$

Total transported TEU per trip (ωL)

$$\omega L = \omega l * xTEU$$

3.5.2 Economic parameters

The economic parameters were divided into capital expenses (CAPEX), operational expenses (OPEX), as well as voyage expenses (VOYEX) where each includes additional cost items.

3.5.2.1 CAPEX

Capital expenses were based on a yearly basis since a financial balance sheet analysis are based on 365 days. However, the operating expenses were calculated on the operating time per year (T), which covers 360 days. Within the capital expenses, a depreciation (j) of 25 years was used to reflect the benchmark lifetime expectancy of a newbuilt container vessel (Ge et al., 2021). The interest rate (i) was calculated as the outcome of a yearly capital expense on the Ship newbuild price ($C_{newbuild}$). The capital cost parameters were then converted from an annual basis to a capital cost per trip.

Total capital expenses per trip (C_{capex})

$$C_{capex} = ((C_{newbuild}/25/365) * N) + ((C_{newbuild} * i/25/365) * N)$$

3.5.2.2 OPEX

The cost parameters that covered the operation expenses includes the sum of operating cost per trip (C_{op}), port and disbursement account cost per trip (C_{PDA}), total container depreciation and maintenance cost per trip (C_{cont}), terminal handling charge per trip (C_{thc}), total crew cost per trip (C_{crew}) as well as vessel maintenance and repair cost per trip ($C_{m\&r}$); where all commonly were calculated on an operational basis of 360 days, which gave the operational expense per trip as per below.

Total operational expenses per trip (C_{opex})

$$C_{opex} = C_{op} + C_{PDA} + C_{cont} + C_{thc} + C_{crew} + C_{m\&r}$$

3.5.2.3 VOYEX

The voyage expenses (C_{Voyage}) are dependent on factors that differed based on the outcome of routing alternative. If the outcome of routing were around the Cape of Good Hope, then the cost parameter Suez Canal toll per trip ($C_{canaltoll}$) would be rejected and considered null. During port stay, the vessel consumptions a given amount of marine gas oil for each outcome of routing ($a_{FuelPort}$) Apart from this, the daily consumption of heavy fuel oil ($a_{FuelHFO}$) and marine gas oil ($a_{FuelMGO}$) results as a function of average sailing speed (v), which fluctuated depending on the state of the market. The fuel option was based on whether the sailing days operated in ECA-area (te), sailing days non-ECA area (t), or in port (tp). Price for heavy fuel oil (P_{HF}) and marine gas oil (P_{MG}) were set from a monthly average around the present value of the market timeline, which was at the same timeline as the received freight rates.

Voyage expenses per trip transiting Suez Canal route ($C_{VoyagSuez}$)

$$C_{VoyagSuez} = C_{canaltoll} + ((a_{FuelHFO} * t) * P_{HF}) + ((a_{FuelMGO} * te) * P_{MG}) + ((a_{FuelPort} * tp) * P_{MG})$$

Voyage expenses per trip for Cape of Good Hope route ($C_{VoyagCoGH}$)

$$C_{VoyagCoGH} = ((a_{FuelHFO} * t) * P_{HF}) + ((a_{FuelMGO} * te) * P_{MG}) + ((a_{FuelPort} * tp) * P_{MG})$$

3.5.3 Result per trip

The main object of the calculations stemmed behind retrieving an economic result from each series of calculations. By combining the results from capital expenses (C_{capex}), operational expenses (C_{opex}), voyage expenses (C_{voyage}), per trip, a total cost per trip could be defined. Total income per trip (I) were determined by multiplying the spot rate per TEU ($P_{spotrate}$) with total amount of TEU transported by trip (ωL). With this data, total result per trip (π) and profit margin per trip (δ) were defined as:

Result per trip (π)

$$\pi = (P_{spotrate} * \omega L) - (C_{capex} + C_{opex} + C_{voyage})$$

Profit margin per trip (δ)

$$\delta = \pi \,/\, (P_{spotrate} * \omega L)$$

4. RESULTS

Based on the assumptions made, data gathered, and model built, these are the results showing the economic impact of the conflict, together with operational findings which point towards economies of scale benefits and general economic implications with circumnavigating the Suez Canal. The results will provide an insight into the financial aspects for each market condition, vessel size and route.

4.1 Financial results per trip

Below are the gross profit results from the data gathered, put into different market conditions, visualizing the two different routings for different vessel sizes.

Gross profit ($) Profit margin (%) per trip	**18 000 TEU**	**19 000 TEU**	**20 000 TEU**	**21 000 TEU**	**22 000 TEU**	**23 000 TEU**	**24 000 TEU**	**25 000 TEU**
Suez Low	**$ -536 099**	**$ -476 879**	**$ -431 756**	**$ -368 494**	**$ -331 111**	**$ -293 692**	**$ -280 776**	**$ -238 413**
	-6,20%	-5,20%	-4,50%	-3,70%	-3,10%	-2,70%	-2,40%	-2,00%
COGH Low	**$ -468 613**	**$ -432 912**	**$ -410 894**	**$ -374 046**	**$ -337 512**	**$ -301 029**	**$ -264 733**	**$ -229 532**
	-5,40%	-4,70%	-4,30%	-3,70%	-3,20%	-2,70%	-2,30%	-1,90%
Suez Medium	**$3 256 769**	**$3 529 970**	**$ 3 801 360**	**$ 4 078 259**	**$ 4 329 454**	**$ 4 580 639**	**$ 4 807 387**	**$ 5 063 621**
	25,80%	26,50%	27,20%	27,70%	28,10%	28,50%	28,60%	28,90%
COGH Medium	**$3 392 019**	**$3 646 583**	**$ 3 901 991**	**$ 4 157 489**	**$ 4 412 767**	**$ 4 667 976**	**$ 4 923 037**	**$ 5 177 081**
	26,90%	27,40%	27,90%	28,30%	28,70%	29,00%	29,30%	29,60%
Suez High	**$8 864 151**	**$9 459 677**	**$10 053 271**	**$10 652 347**	**$11 225 759**	**$11 799 169**	**$12 348 165**	**$12 926 790**
	45,60%	46,10%	46,50%	47,00%	47,20%	47,50%	47,60%	47,90%
COGH High	**$8 656 226**	**$9 223 739**	**$ 9 792 017**	**$10 360 375**	**$10 928 534**	**$11 496 630**	**$12 064 593**	**$12 631 632**
	44,50%	44,90%	45,30%	45,70%	46,00%	46,30%	46,50%	46,80%

Table 4: Financial results per trip divided into market condition, route choice and vessel size. Results are shown in USD and profit margin as percent. Note the negative results for the low market conditions.

Above are the actual financial results for the different market conditions and for each specific vessel size. For a low market, both the Suez Canal route and COGH route will prove unprofitable. The deficits experience improvements as the vessel sizes increase for all market conditions. Once the market conditions improve, so does the spot market price, sailing speed and load factor. These factors prove to be significant once the market goes from low to medium and are furthered improved once the market becomes high.

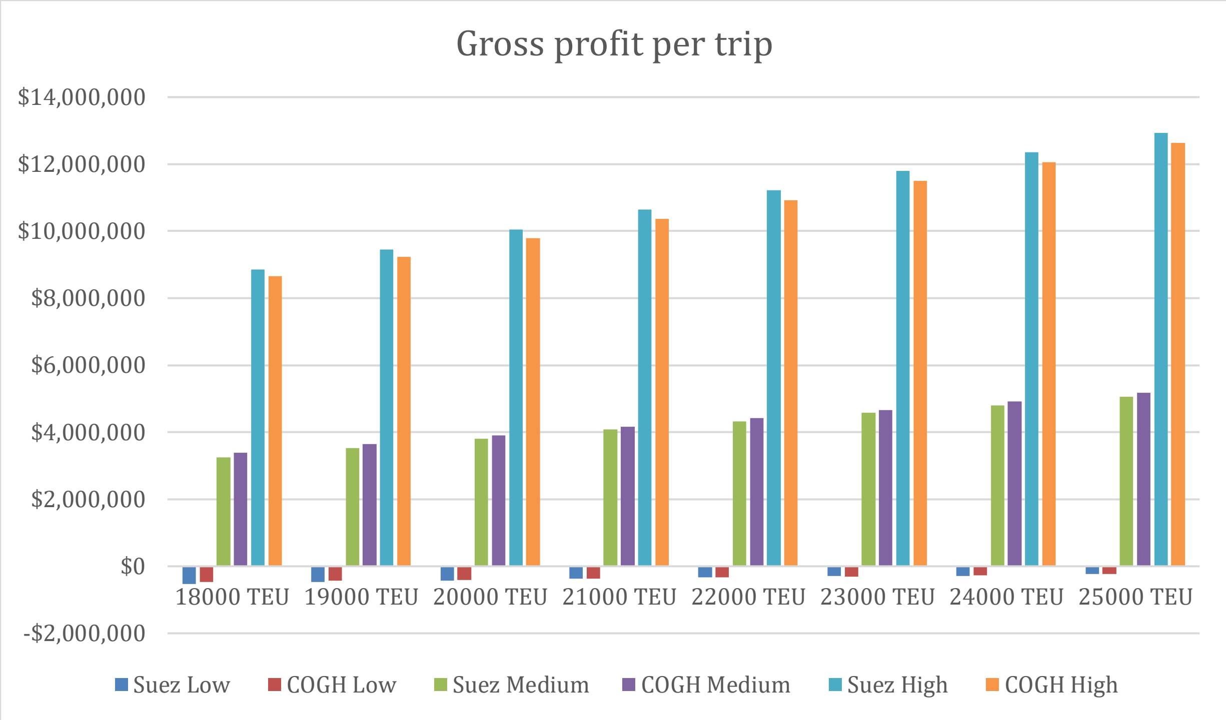

Figure 2: Same data as table 4 but visualized in bar charts. Note the constant growth in gross profit as vessel size increases as well as the negative gross profit results in the low market condition.

The results can be further examined in a graph like above. The low markets are in a deficit, whilst the medium and high market are profitable. In low and medium markets, the Suez route consistently perform poorer than the COGH route. This is a result of the Suez Canal toll being more expensive than the additional bunker consumed for the longer COGH route. For the high market, the Suez Canal is the best performing route to take.

Another important factor to consider is the number of trips a liner shipping company can take depending on routes. The sailing speed is determined on the market conditions, where the better the market performs, the faster the vessels sail. This is naturally to be able to make as much money as possible. Only considering the westbound leg, a liner shipping company will be able to complete one more westbound trip in a medium and high market when passing through the Suez Canal. In effect, this means between 3,3 MUSD – 5 MUSD extra gross profit in a medium market and 8,9 MUSD – 12,6 MUSD for a high market (see Table 4).

Market	Speed (knots)	Sailing days	Annual amount of loops	Westbound trips	Eastbound trips
Suez Low	18	29	12,6	6	6
COGH Low	18	33	11,1	6	6
Suez Medium	20	26,3	13,9	7	7
COGH Medium	20	30	12,2	6	6
Suez High	22	22	16,6	8	8
COGH High	22	27,2	13,4	7	7

Table 5: The table shows how many loops each market condition provides on an annual basis. Note the increase in number of loops on the medium and high market for the Suez Canal route choice. This will subsequently provide more revenue and profits.

4.2 Financial break-even metrics

Below presents the break-even metrics used to determine when each route and vessel size will be profitable under each spot-market condition.

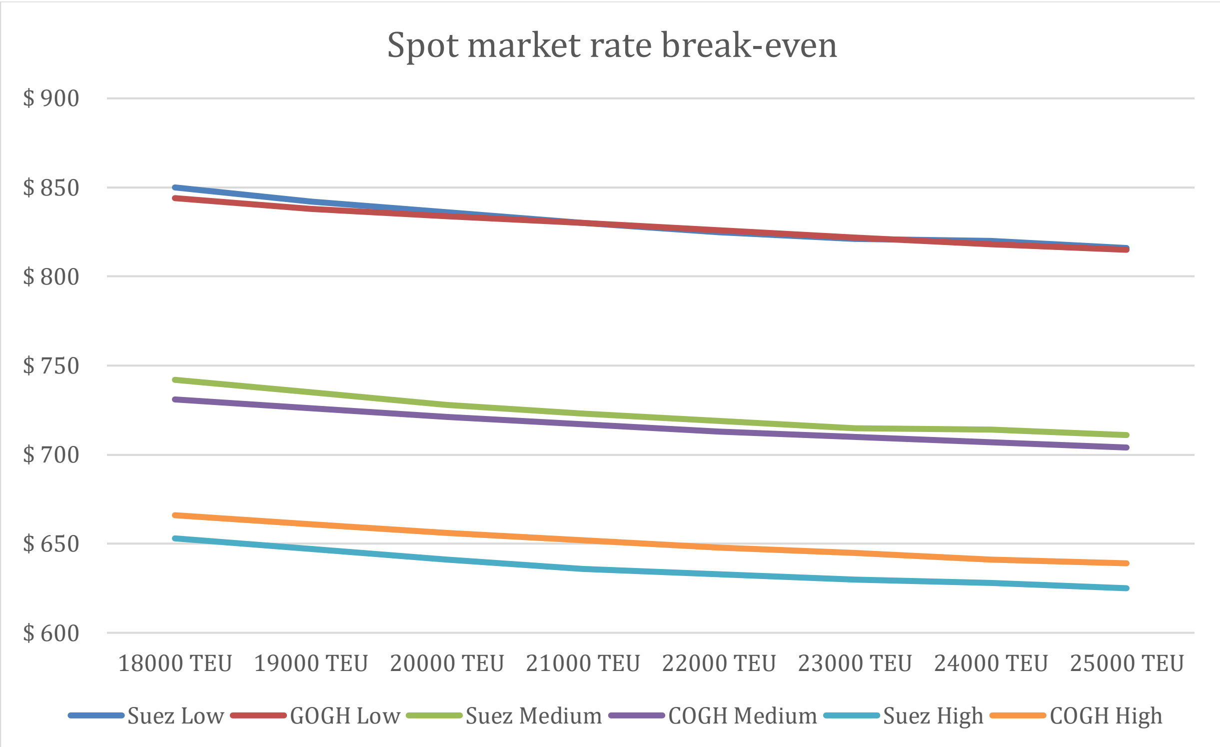

Figure 3: The spot market rate that is required per market condition, route choice and vessel size to break even. Note that only on a high market is the Suez Canal route more beneficial than the COGH route. Y-axis begins at 600 USD.

The spot market break-even metrics for the low market are identified as the top two lines in the graph. The differences between the Suez Canal route and COGH route are seemingly nonexistent except for the 18.000 TEU vessels. For an 18.000 TEU vessel, to pass through the Suez Canal in a low market, a decrease by 1 USD in spot market rate will have an effect of -

10 000 USD for the profit. For the medium market, the COGH route is consistently the best route in terms of break-even spot market. For a spot market rate of 731 USD/TEU in a low market, the COGH route will break even, but the Suez Canal route will have the same effect as above and see a loss of 132.000 USD. As for the high market, the Suez Canal route outperforms its competitor in at every vessel size. One reason for this is because the Suez Canal toll is so small in comparison to the income, making it insufficient. Another reason is also that the faster Suez route splits the fixed depreciation costs less per trip than the slightly slower COGH route does. Performing the same comparison as the other markets, the COGH route will lose the liner shipping company 205.000 USD on the same break-even spot market rate that is acceptable for the Suez Canal route. The importance of having a low break-even income base will prove important when the market sees big fluctuations in the spot market. It's important to note that the liner shipping companies have limited possibilities to influence the spot market rates.

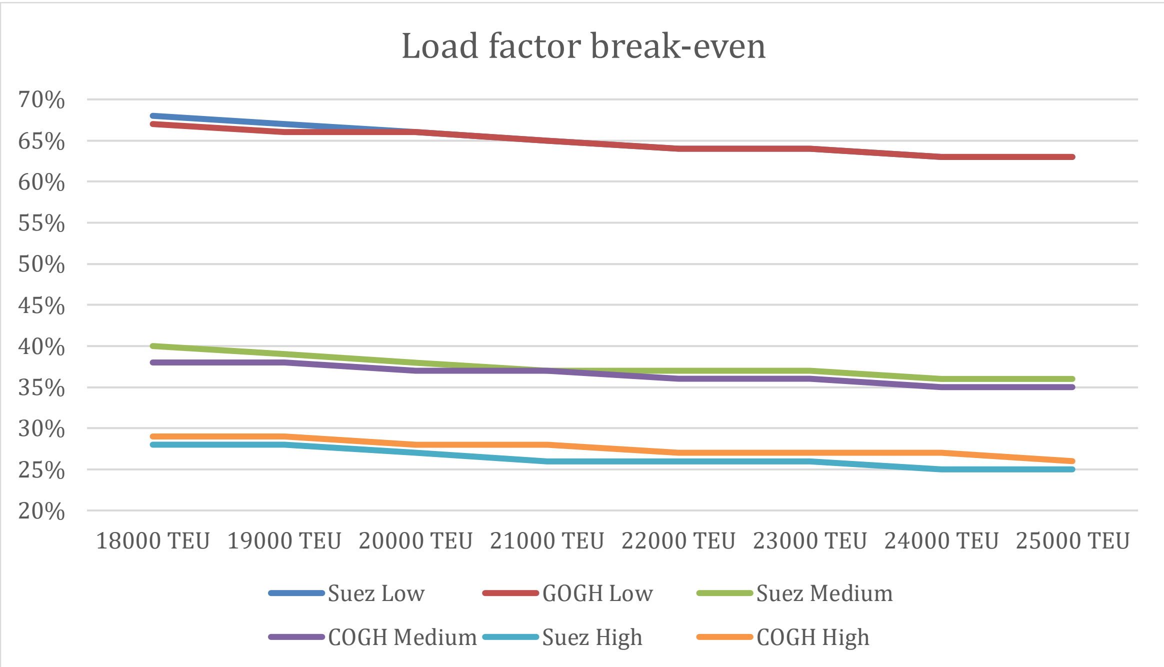

Figure 4: Load factor break even proves a correlation with the spot market break even. Similar tendencies can be seen here, with a steady decrease in required load factor as the vessels increase in size. Note the Y-axis begins on 20%.

The load factor break-even is based on the amount of loaded container, i.e., the income of the company, in comparison to the total vessel capacity. The load factor is dependent on the spot market rate where the load factor increases by the health of the market. For a low market, the spot market has been set to 60%, medium market 70% and for the high market 90%. As the graph above indicates, the low market will always experience a loss if the load factor is below 67-68%. COGH route proves able to facilitate a slightly lower load factor for 18-19 thousand TEU vessels but are along the way evening out the advantage. For the medium market, the COGH route consistently perform better, once again allowing for slight fluctuations in the market. For an 18.000 TEU vessel in a medium market, the Suez Canal route will lose 128.000 USD on a 38% load factor whilst the COGH route would be making a slight profit. As for the high market, the Suez Canal route will cope with a lower load factor, once again proving the balance between the Suez Canal toll and speed mentioned under the spot market rate break even.

4.3 Route specific cost-items

Below is a presentation of the cost-items that change depending on which route the liner shipping company decides to take.

Below is the specific cost items and their respective cost type that differs depending on route choice:

Cost item	Cost type
Depreciation per trip	CAPEX
Interest rate per trip	CAPEX
Total container depreciation & maintenance cost per trip	OPEX
Total crew cost per trip	OPEX
Vessel maintenance per trip	OPEX
Suez Canal toll	VOYEX
HFO consumption	VOYEX
MGO consumption	VOYEX
MGO port consumption	VOYEX

Table 6: The cost items from the model that are dependent on route choice, i.e., changing when time and/or sailing speed increase or decrease. Categorized in the right-hand column as cost type.

For a low market condition, the following is a representation of the total costs on each vessel size for each route choice:

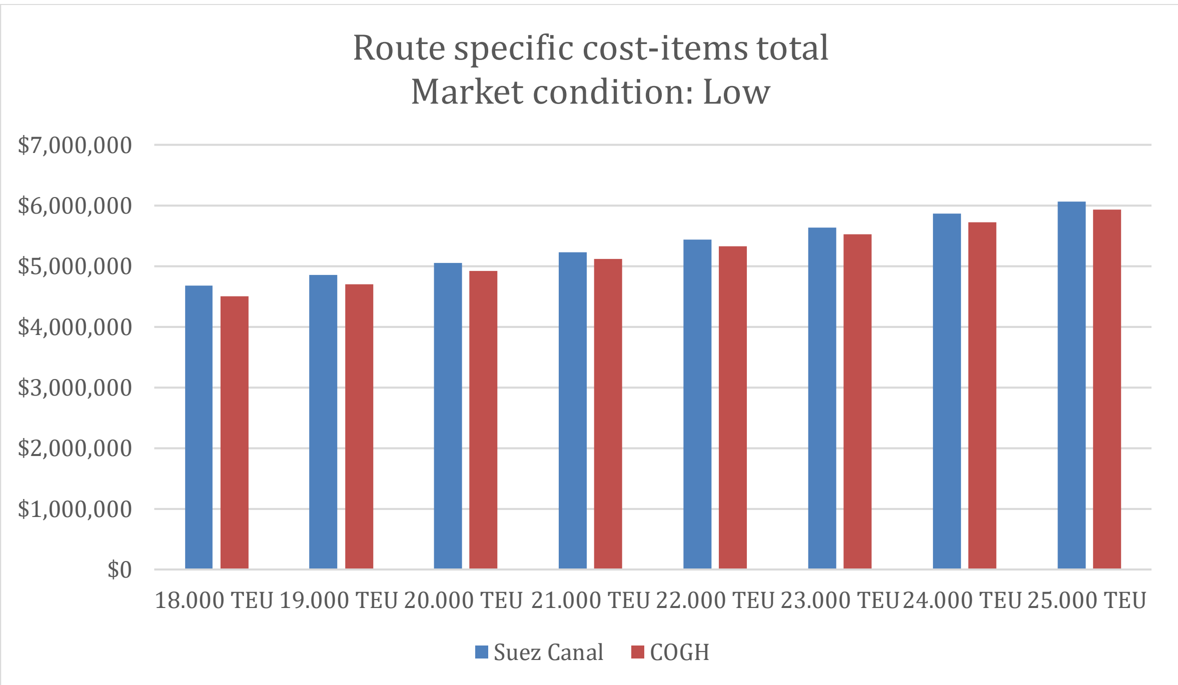

Figure 5: The route specific-cost items total in a low market condition. Note the slightly higher Suez Canal route, explained by the Suez Canal toll.

The graph above visualizes that under a low market condition, the fluctuating cost items depending on route choice, proves the COGH route to be more cost effective.

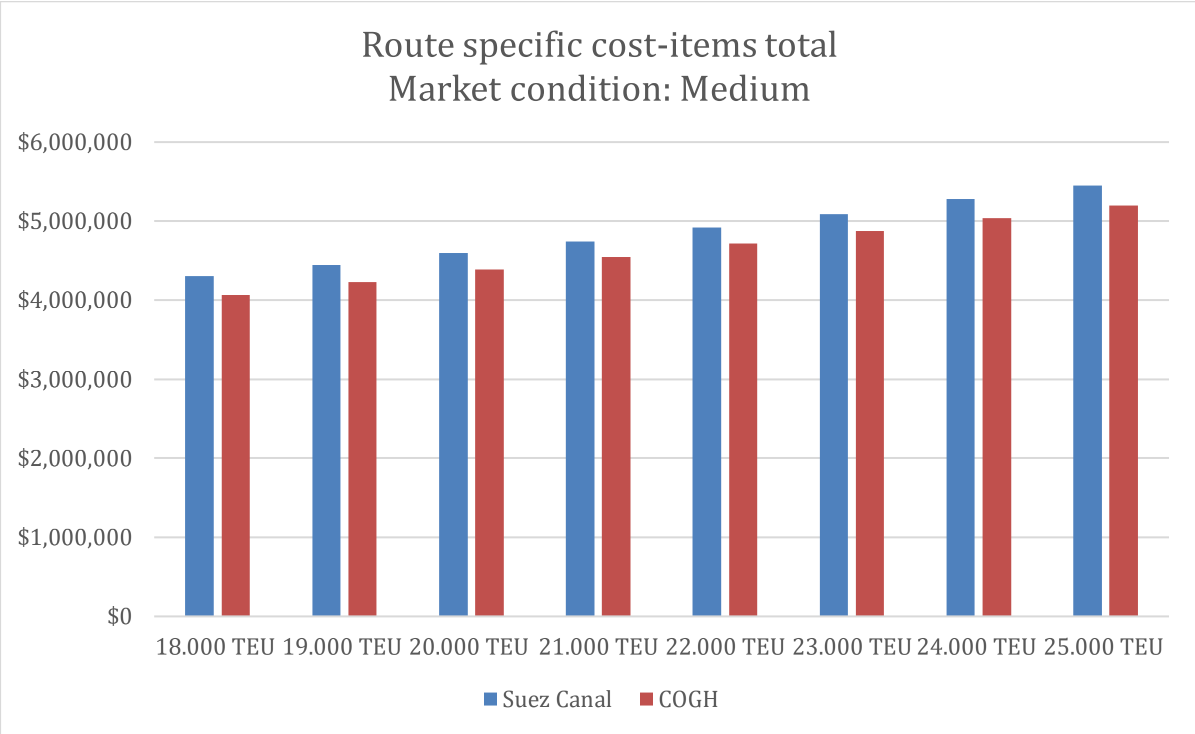

Figure 6: The route specific-cost items total in a medium market condition. Note the slightly higher Suez Canal route, explained by the Suez Canal toll.

In a medium market condition, the COGH is still more cost effective. The increase in bunker consumption and CAPEX is still not enough to outweigh the Suez Canal toll, which in this instance outweighs the increase bunker consumption and increased CAPEX per trip that the COGH experiences.

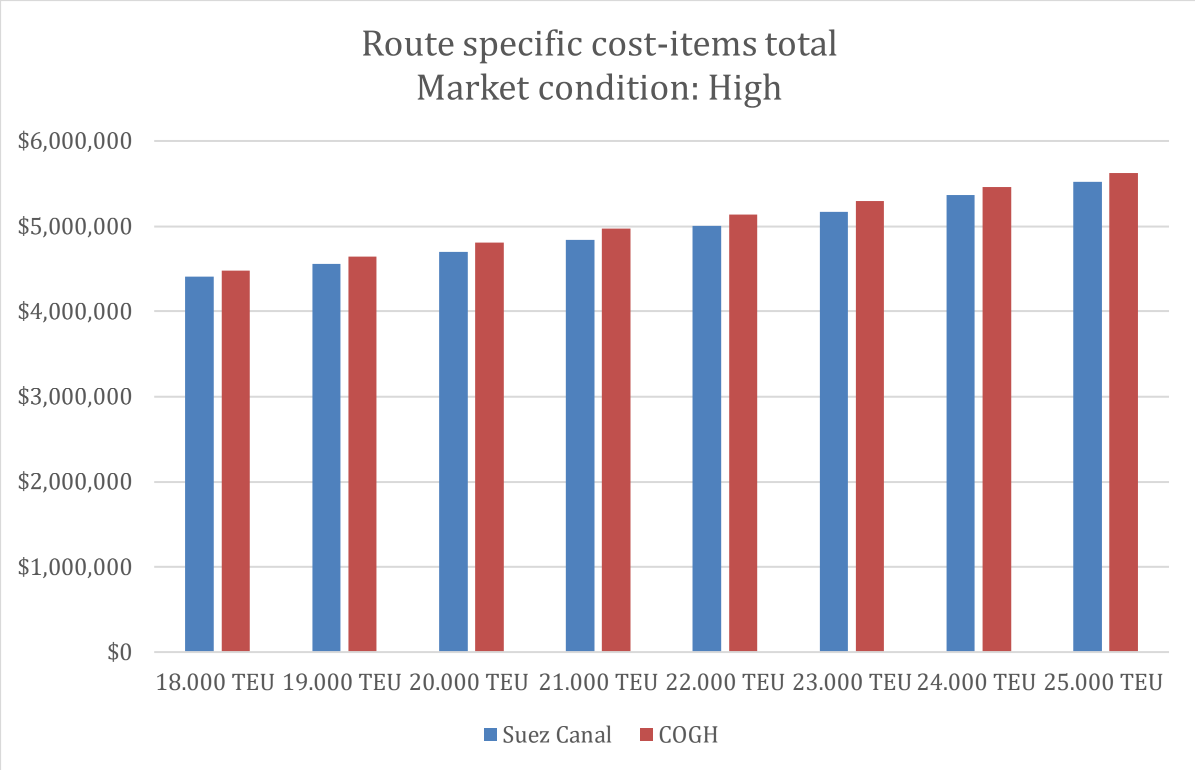

Figure 7: The route specific-cost items total in a high market condition. Note the slightly higher Suez Canal route, explained by the Suez Canal toll.

Although the difference is small, the high market condition is the first time the Suez Canal route proves more cost effective in terms of the route specific costs. The only variable cost item that adjust by improving market conditions is the "Total container depreciation & maintenance cost per trip". Since the load factor increases as the market condition increases, the cost for container depreciation and maintenance for the containers loaded on the vessel increases proportionally.

To summarize the differences in costs, one can compare a standard 18.000 TEU vessel in the different market conditions.

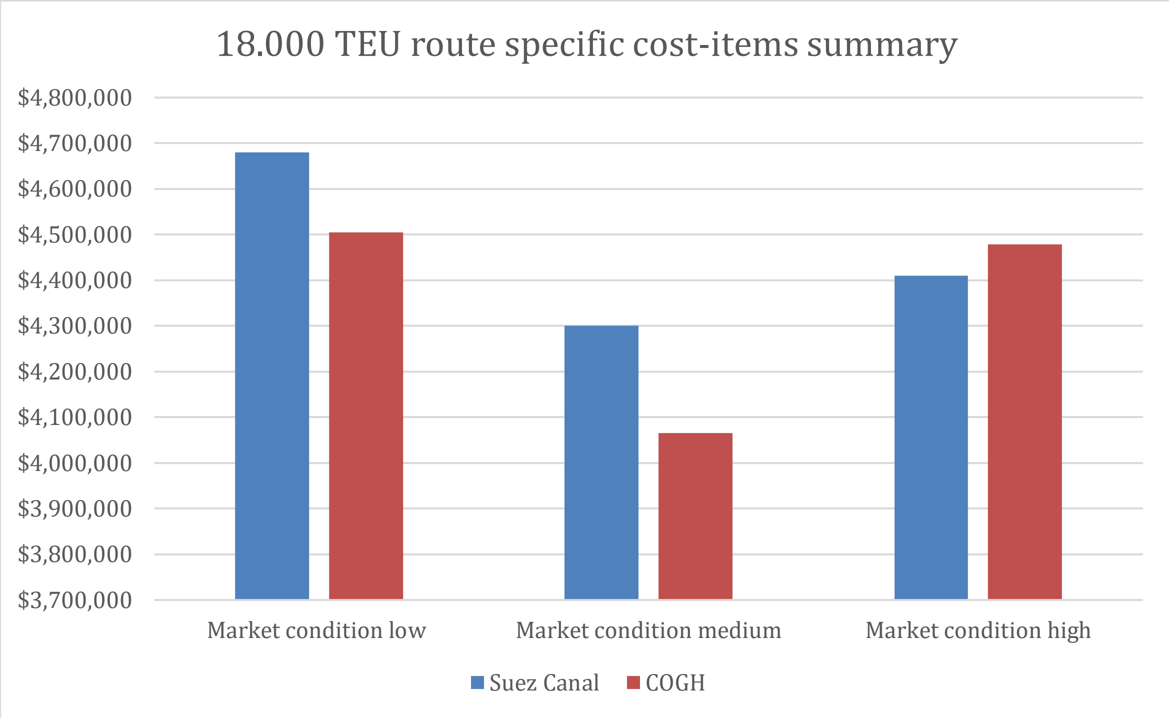

Figure 8: Route specific cost item summary specifically on 18.000 TEU, divided into market conditions. Note the Suez Canal route being more expensive for low and medium markets. Y-axis starts at 3,7 MUSD.

4.4 Red Sea surcharges changes for result

The liner shipping companies has introduced surcharges to combat the increase in expenses of circumnavigating the Suez Canal in favor for the COGH. Below are again those surcharges, now with weighted values based on market share:

Carrier	**Market share**	**Weighing**	**Charge per TEU (USD)**	**Weighted value**
Hapag Lloyd	6,90%	9,00%	500	45
CMA CGM	12,70%	16,60%	325	54
HMM	2,70%	3,50%	500	18
MSC	19,90%	26,00%	500	130
Yang Ming	2,50%	3,30%	450	15
Maersk	14,60%	19,10%	700	134
One	6,30%	8,20%	1000	82
COSCO	10,80%	14,10%	750	106
SUM				**584**

Table 7: RSS charges gathered from Table 1 are weighed depending on carrier market share. The final weighted RSS turns to be 584 USD/TEU.

Comparing the regular rates for the different market conditions and adding the weighted average RSS, the spot market rates will see the following increase:

Market condition	**Regular rates**	**Regular rates + RSS***	**Change**
Low	800	1384	42%
Medium	1000	1584	37%
High	1200	1784	33%

*** Weighted average RSS**

Table 8: The weighted average RSS added to the spot rate for each market condition. In the right-hand column, the increase can be shown.

Since the change for the low market rates is the steepest, naturally this will reflect in the overall gross profit and profit margins. The most significant increase is in the low markets where we can observe a gross profit increase of 1176% for the Suez Canal route and 1346% for the COGH route. With an increasingly healthier spot market, the additional RSS will not make as much difference as the weaker market conditions but will still double the gross profit for the high market. Below table is an extract of the results for 18.000 TEU vessel.

Suez Canal route		Low		Medium		High
Standard rate	$	-536 099	$	3 256 769	$	8 864 151
Standard rate + RSS	$	5 771 101	$	10 615 169	$	18 324 951
Change		**1176%**		**226%**		**107%**

Table 9: For an 18.000 TEU vessel, this table shows the financial result with and without the RSS on the three different market conditions for the Suez Canal route.

COGH route		Low		Medium		High
Standard rate	$	-468 613	$	3 392 019	$	8 656 226
Standard rate + RSS	$	5 838 587	$	10 750 419	$	18 117 026
Change		**1346%**		**217%**		**109%**

Table 10: For an 18.000 TEU vessel, this table shows the financial result with and without the RSS on the three different market conditions for the COGH route.

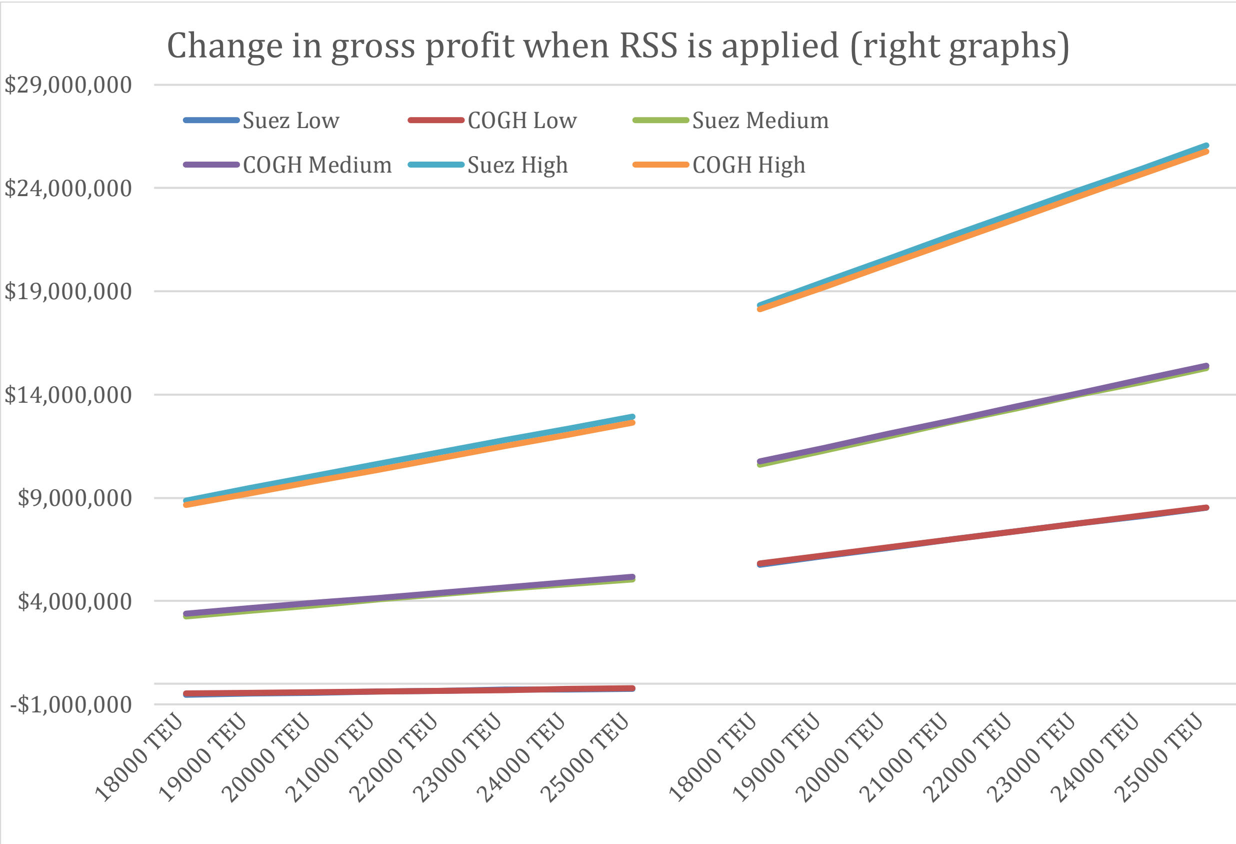

Figure 9: Change in gross profit without RSS applied on the left-hand side, and with RSS applied on the right-hand side. Note the slightly more profitable Suez Canal route on high market.

The increase in gross profit is visualized in above graph where the biggest percentage increase can be seen on the low markets, whereas the higher market still sees an incline, but not as prominent.

4.5 Economies of scale tendencies

In the following metrics, scale benefits can be identified. These are operational or financial benefits when the vessel size increases.

Economies of scale tendencies can be assessed to several metrics in the results, whereas the most prominent is the profit margin increase when the vessel sizes increase. Since the spot market rate remains the same for all vessel sizes, but the total income increase is steeper than the cost increase, a larger ship will under these metrics always produce a larger profit.

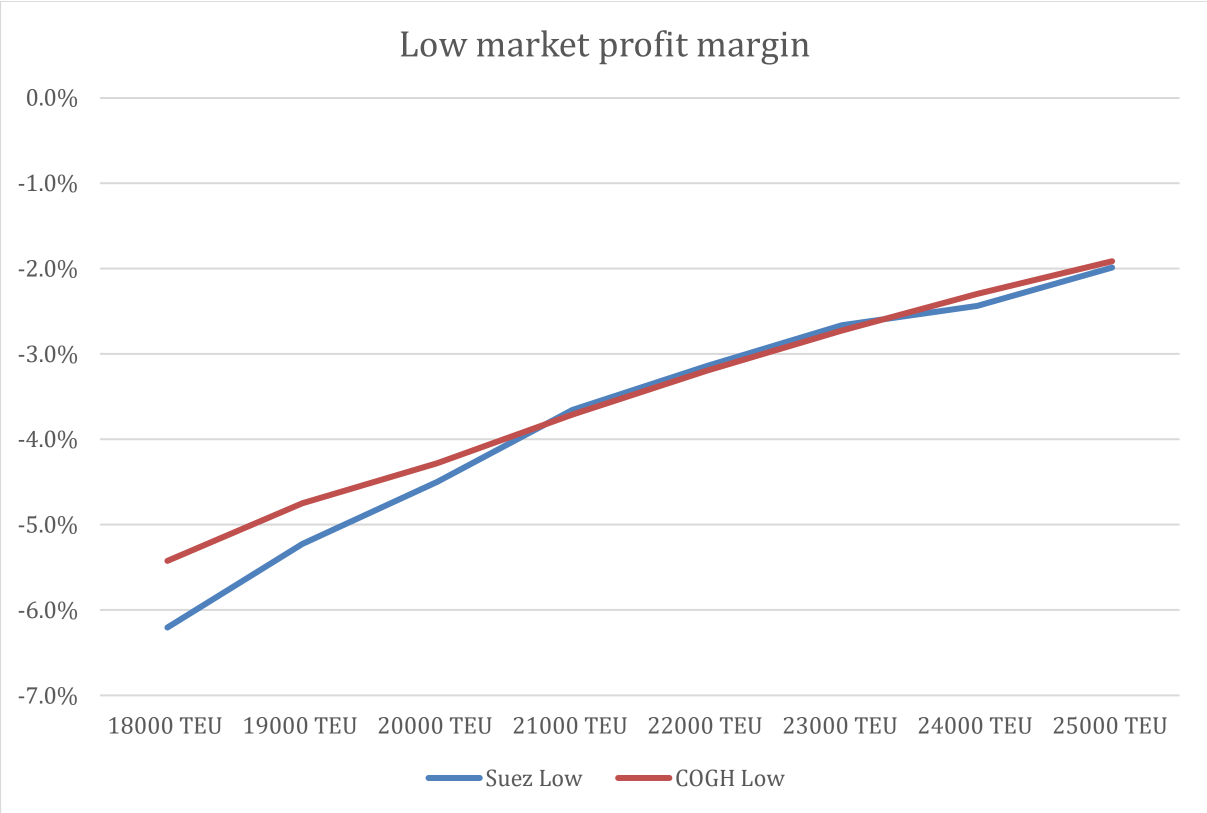

Figure 10: The profit margins on a low market condition distributed over vessel size. Note the poor performance of Suez Canal route for sub 20K TEU vessel.

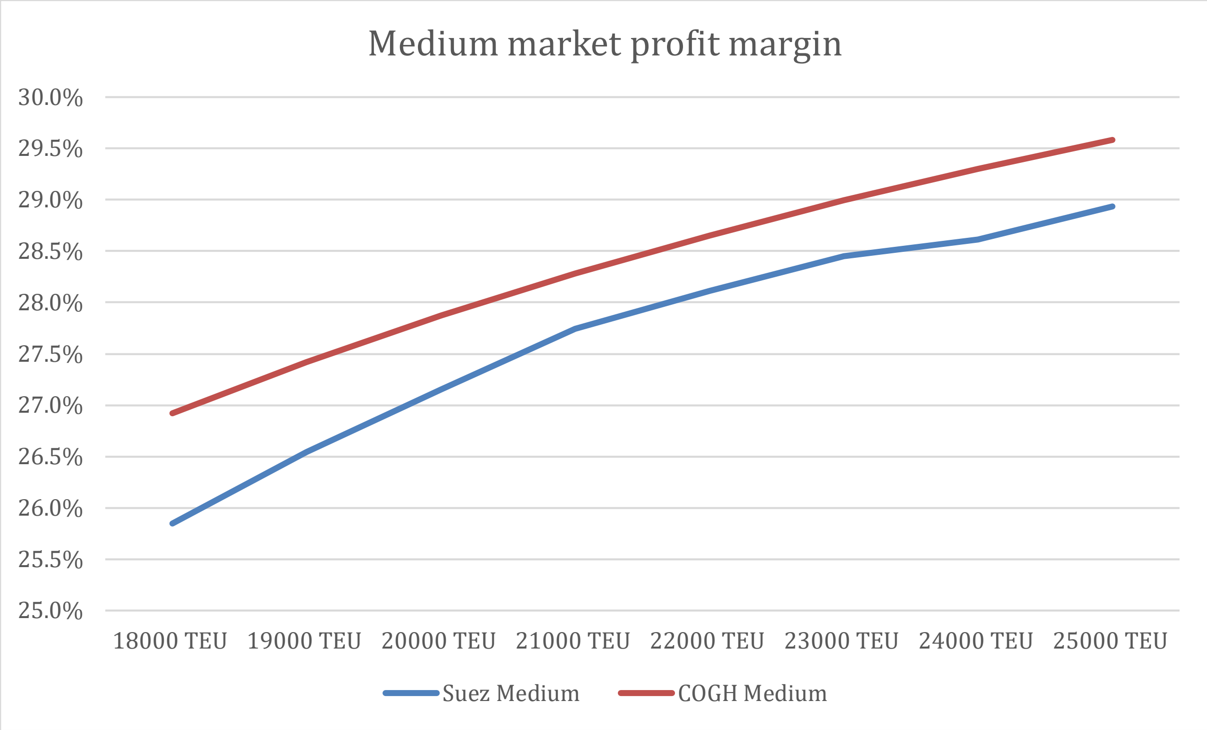

Figure 11: Profit margins for a medium market condition distributed on vessel size. Note the consistently poorer performance of the Suez Canal route. Also, not the Y-axis beginning at 25%.

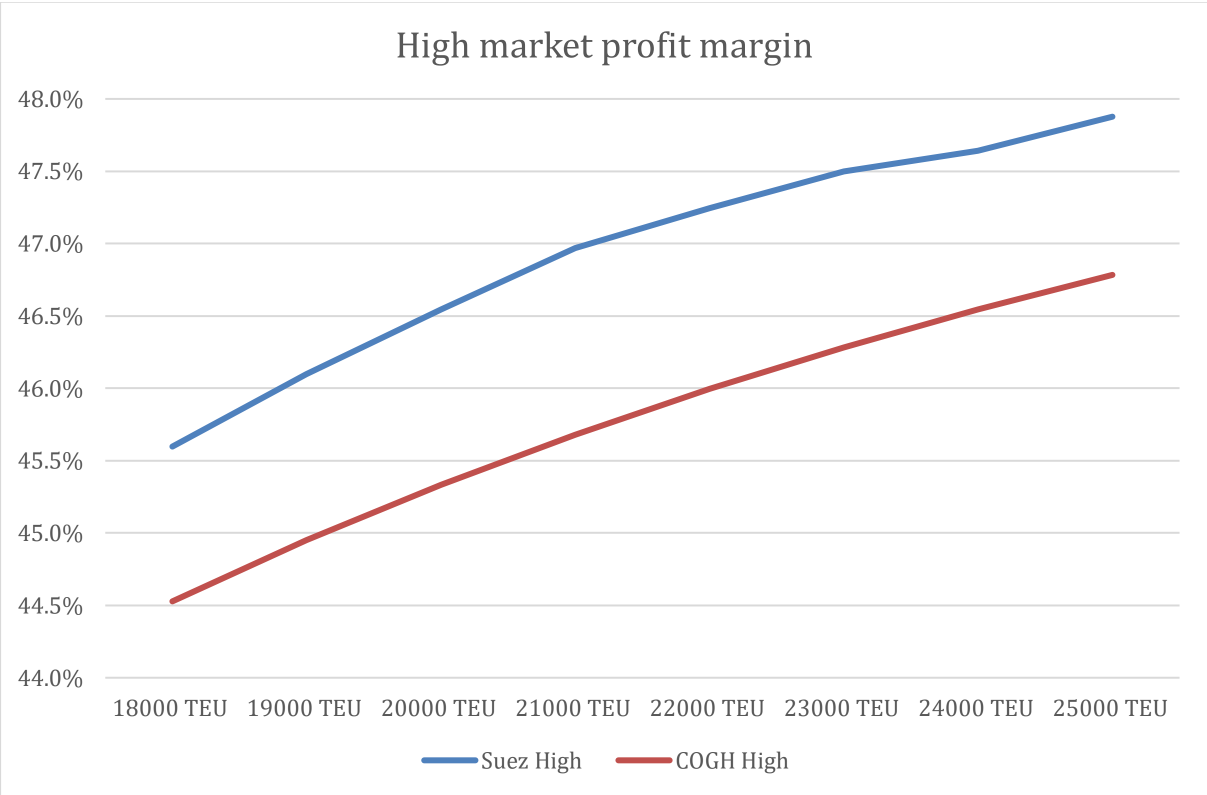

Figure 12: The trend of the Suez Canal route being more profitable than the COGH on a high market condition continues. Note the Y-axis beginning at 44%.

When doing the same comparison but instead comparing the smallest and the biggest vessel in the dataset, we can again see the economies of scale tendencies regarding the profit margin.

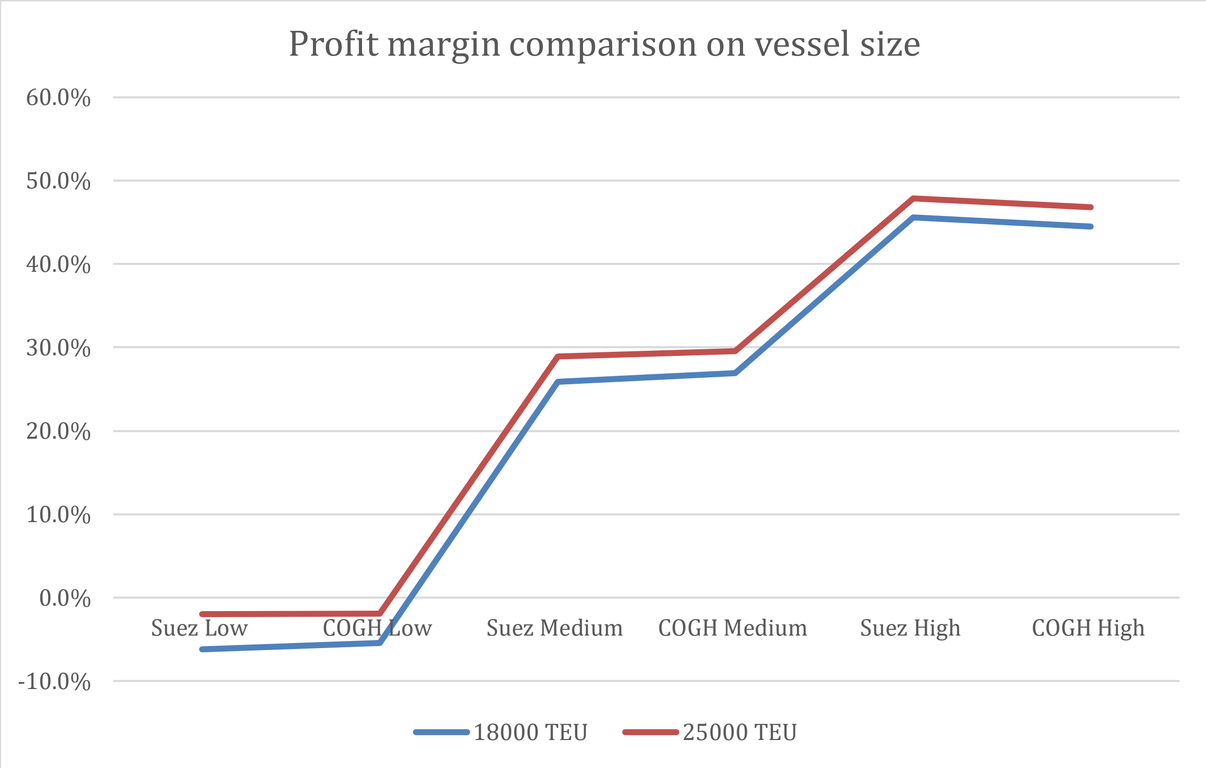

Figure 13: A visualization of economies of scale benefits. Even in poor market conditions, the larger vessel (25.000 TEU) performs better than the 18.000 TEU vessel. The trend continues when market conditions become better.

When breaking down the cost items, one can determine that the cost indeed increases, but the table below indicates that the cost item slopes are less significant than the income slope. The slope coefficient is a metric used to numerically determine the slope of a line and can be calculated using slope = (X2-X1)/X2. In this example, X2 is the 25.000 TEU income or cost and X1 is the 18.000 TEU income or cost.

	Market condition	Slope
Income	Low market	0,28
	Medium market	0,28
	High Market	0,28
Average		**0,28**
Cost	Suez Low	0,25
	GOGH Low	0,255
	Suez Medium	0,249
	COGH Medium	0,253
	Suez High	0,249
	COGH High	0,249
Average		**0,251**

Table 11: A visualization of the economies of scale benefits. The slope of income is higher and more consistent than the slope of cost, eventually guaranteeing profit if the vessel size is large enough.

Above is a representation that the income slope is steeper than the cost slope, indicating that with an increasing income capacity i.e., larger vessel, eventually the bigger vessel sizes will break even and later make increasingly larger profits.

5. DISCUSSION

The discussion will cover the financial effects from the initiation of the Red Sea surcharges and whether they introduced these surcharges to cover the additional expenses, or just to seize the opportunity to severely increase profits. The discussion will also touch upon the actual changes in expenditures, the characteristics of those and what role they play in the big picture. This chapter will also discuss the methodology and its reliability and validity.

5.1 Result discussion

The results section will touch upon the theory and revert to the actual results of the paper. Firstly, the Red Sea Surcharges actual effect on the profit margins. Secondly, the actual financial results and the cost items effect on each other under certain market conditions.

5.1.1 Red Sea Surcharges

As seen in the results section, the RSS implementation has proven extremely successful for the liner shipping companies, boosting profits significantly. In a low market, they experience a profit increase of just above 1000%, an increase of 200% for the medium market and a doubling of profits in a high market. Amidst a pressed supply chain resilience situation, can this increase be accepted? One might imagine that the liner shipping companies deliberately introduce these surcharges to capitalize on an event that neither the transport service provider nor the transport service buyer can control. According to (Bose, 2024), the liner shipping companies has also said that the circumnavigation of the Suez Canal in favor for the COGH route will take 10-14 days longer. This is through this paper's calculations proven false. If assuming a sailing speed of 18 knots, corresponding to the low market calculations, the actual sailing time increase is 4 days, far from the information provided from the liner shipping companies. Is this a way for them to hedge for transit disruptions and port congestions or is it a way for them to defend the implementation of the RSS charges. We can also observe that the route specific cost items, i.e., the charges directly linked to the routing choice made by the liner shipping companies does not change drastically depending on what route is to be taken. This is further proof that the liner shipping companies' introduction of the RSS charges are either too drastic or aimed at covering other costs associated to the operations, like port disruptions.

The applied RSS is an overexaggerated rate that has considered too much of the additional costs associated with the current Red Sea crisis and subsequent circumnavigation of the Suez Canal. When weighing the charges from (Solsvik & Trompiz, 2023b), the numbers speak for itself with a weighted average RSS value of 584 USD/TEU. This in context, means that the liner shipping companies will artificially push the spot market rates upwards 42% in a low market, 37% in medium and 33% in a high market. This in turn leads to significant bottom line increases in all market conditions, with the largest increase in profits being in the COGH low market condition of an increase of 1346% in profits. For the medium markets, unaware of routing decision, they see just above 200% increase and for the high markets they see roughly a doubling of profits, again no matter the routing choice.

5.1.2 Financials

The calculations were done on a “per trip” basis only visualizing the financial implications from one trip i.e., Shanghai – Antwerp. When we in section calculated the same circumstances but on a full calendar year some interesting results emerged. For the medium and high market, the Suez Canal route managed to incorporate two more trips or one loop more than the COGH route. This is an important metric in the sense that more trips are directly linked to an increase in overall revenue, as well as in medium and high market conditions an increase in profits. Subsequently, this might be one of the reasons RSS were introduced, to cover for the loss of revenue and profits when circumnavigating the Suez Canal. The sailing speed is also incorporated in the route specific costs, where a faster sailing speed will further dilute the costs associated with the amount of sailing days. Again, since the calculations were made on a “per trip” basis, the faster you sail, the lesser some of the route specific costs will be and can for instance in the high market condition prove more cost effective, outweighing the Suez Canal toll. Since the market is cyclical and good nor bad times last forever, the liner shipping companies will likely take the Suez Canal route in medium and high markets.

Because of the increase in sailing time when circumnavigating the Suez Canal, all cost items dependent on time, will be affected. Capital expenses, i.e., depreciation and interest rates per trip are affected by a longer sailing time. With a longer route, the capex cost will be diluted along more days, which increase on a per trip basis and subsequently yearly. Another cost item affected by the time discrepancy is the operational expenditures. The container depreciation and maintenance, along with vessel maintenance and total crew cost will on a per trip basis will see an increase for a longer sailing route. Obviously, an increase in bunker consumption will be identified once a vessel sails a longer route. The COGH route is roughly 3300 nautical miles longer, which will increase the HFO consumption. A big proportion of the VOYEX is the Suez Canal toll. Ranging from roughly 700.000 USD to 835.000 USD this cost item is nevertheless significant. This phenomenon can be examined in the low and medium markets for Suez Canal, where the toll plays a pivotal role and outweighs the increased bunker costs for circumnavigating the canal.

For a low market condition, the break-even range from 68% load factor to 63% depending on vessel capacity. The decrease can be considered linear, and the routing choice does not significantly affect the load factor break even points. We do see a slight difference between Suez Canal and COGH for 18.000 and 19.000 TEU vessels where the Suez Canal route requires 1 percentage-unit more loaded container to break even. For the medium market condition, the break-even range from 40% load factor to 35% depending on vessel capacity. The COGH route performs better throughout all vessel sizes, requiring on average 1-2 percentage units less loaded to cover the break-even point than the Suez Canal route. For a high market condition, the break-even range from 29% load factor to 25% depending on vessel capacity. Unlike the previous market conditions, this is the first time the Suez Canal route performs better than the COGH and enjoys on average 1-2 percentage units less loaded to cover the break-even point than the COGH route.

Apart from the route choice, it's clear that a better market condition, i.e., a higher spot rate, will severely affect the vessel space utilization required to cover the cost. Once again, we observe that the Suez Canal toll makes up such a significant portion of the total cost items, that the economic benefits of passing through the canal can only be experienced in a high market condition. The spot market break-even and load factor break-even are interlinked in an intricate system. In a low market condition, the generic load factor is low, requiring the spot rate to be high to cover the costs and subsequently reach a profitable operation. We can also see that with larger vessels, the spot rate break-even decreases, this is because the cost items do not increase at the same rate as the income does.

Lastly, the prominent economy of scale benefits experienced regarding profit margins are clear and understandable. With an increase in vessel capacity, the increase in income will increase faster than all the cost being CAPEX, OPEX & VOYEX. This phenomenon opens the discussion of where the limit to vessel size and economies of scale ends. The results will not provide any limitation to the benefits, the profit will keep increasing. The actual limits, i.e., geographical limitations, berthing limitations, and extensive port stays, are the main factors deaccelerating the liner shipping companies' pursuit of increasingly larger vessels. Even though it might be tempting to pursue even larger vessels, the figures speak to that a low market will not turn profits for the companies. One shall also understand that the spot market rates might be even lower than what this paper considerers a "low" market. The possibility of even lower market under an extended period is fully feasible, severely impacting the profits for liner shipping companies. Another factor that will determine the outcome of the calculations and affect the profits is our assumptions that the ship is fully financed via lending. The interest rate is based on the amount borrowed to purchase the vessel. If some of the vessel is financed by the company's own equity, the interest rate will be reduced.

5.2 Method discussion

The method section discusses the model accuracy, statistical significance and whether the parameters are presented correctly. It also entails pros and cons with the method selection and if the option of quantitative study supports the reliability and validity of conducting a case study.

5.2.1 Model accuracy

The model calculation did not show any errors in how the result was retrieved. However, it was difficult to prove whether the data was accurate or not. Since data were retrieved from various sources, there may have occurred sources of error in the data gathering phase. Since the case study has included a large set of parameters, it hasn't been possible to find a single source which contained data for each parameter. Therefore, many sources of information have been used, which can be seen as a reliable advantage. However, to gather data from many sources to calculate a single case may on the other hand cause a barrier of information and may instead result in small errors. For instance, the capital costs were based on an interest rate gathered from a reliable source, were a percentual value were given to calculate on the total value of the vessel investment. This percentual value is accurate if ensured to follow change in fluctuation, while calculating the interest rate on total value of investment may not always be the case since it could have partly been cash-financed.

5.2.2 Linear Regression

As mentioned in the methodology, a linear regression model has been used to calculate nonexistent data for certain vessel sizes between the 18.000-25.000 TEU range. The linear regression model has mainly been used to collect data for the fictional 25.000 TEU vessel. Some variables which were gathered through linear regression may turned out to be inaccurate, since all the sailing and economic parameters doesn't increase in a linear movement. However, no other approach could be implemented on the calculations since this is the mathematical method which has been implemented from the reference paper.

5.2.3 Non-appearance parameters and left behind sources

This numerical case study mainly covers the financial result for one vessel operating in a certain trade route from far east Asia to northwest European continent. It is a specific case in which many parameters and sourced had to be left behind. Economic parameters such as cost for office and personnel for a company, sailing parameters like weather factor or voyage cost for sudden disruptions has not taken into consideration as stated in the delimitation chapter. Therefore, it was difficult to identify realistic results from each financial result since many factors were left behind.

5.2.4 Method Reliability and Validity

The reliability of the method is ensured by the accurate collection and processing of data. This entails gathering data from a variety of sources which, in the model accuracy, also introduce the potential errors and inconsistencies in the data. By taking on a case study with a large collection of parameters, it's clear to assure that a quantitative study was the valid method option. If there were a need to understand the deeper meaning and insight to a social phenomenon rather than quantifying elements, it would have been strengthening to use a qualitative approach for the case study. We can therefore conclude that the choice of a quantitative methodology was the correct method option.

6. CONCLUSION

Below are the final thoughts in relation to the purpose and questions we aimed to answer in this paper. Looking back at the papers purpose of examining the cost and logistical difficulties in this geopolitical situation, provide an optimal vessel size and capacity utilization in different market conditions as well as give a nuanced understanding of the trade-offs, some valuable insight for the stakeholders and highlighting the optimal utilization of maritime routes, below will conclude this paper and hopefully fulfill the purpose and its questions.

6.1 Research question 1

To execute the purpose of this research paper, the first research question has been presented as follows:

"What are the actual extra costs of circumnavigating the Suez Canal around Cape of Good Hope in a liner shipping trade from far east Asia to the northwest European continent?"

The calculations gathered from the financial model has concluded that:

- The extended sailing time through the Suez Canal impacts various cost factors. Capital expenses, like depreciation and interest rates per trip, spread out over more days, increase on a per trip and subsequently yearly basis. Operational expenditures, such as container and vessel maintenance, and crew costs, also rise with the longer route. Bunker consumption rises with the COGH route being approximately 3300 nautical miles longer, increasing HFO usage. Despite increased voyage expenses for circumnavigating the canal, the significant Suez Canal toll, ranging from $700,000 to $835,000, remains a pivotal cost factor, especially in low and medium markets where it outweighs the increased voyage expenses such as bunker.

6.2 Research question 2

To execute the purpose of this research paper, the second research question has been presented as follows:

"What is the vessel space utilization required to cover the cost in different market conditions?"

The calculations gathered from the financial model has concluded that:

- In a low market, break-even ranges from 68% to 63% load factor, linearly decreasing with vessel capacity, unaffected by routing. Yet, Suez Canal demands 1% more loaded containers for 18,000-19,000 TEU vessels to break even. In a medium market, break-even ranges from 40% to 35%, favoring COGH, needing 1-2% less load to break even than Suez Canal. In a high market, break-even ranges from 29% to 25%, where Suez Canal outperforms COGH, requiring 1-2% less load to break even. Improved market conditions significantly impact vessel space utilization for cost coverage, especially as Suez Canal tolls dominate costs, making canal passage economically advantageous only in high markets.

6.3 Research question 3

To execute the purpose of this research paper, the third research question has been presented as follows:

"What is the spot market rate required to cover the cost in different market conditions?"

The calculations gathered from the financial model has concluded that:

- Spot market break-even and load factor intertwine intricately. In low markets, low generic load factors demand high spot rates for profitability, especially with larger vessels where break-even decreases due to income outpacing cost increases. In low markets, spot rates required for profit range from $850/TEU to $815/TEU, with COGH needing $1-5/TEU less than Suez Canal. Medium markets see rates from $742/TEU to $704/TEU, with COGH requiring $6-11/TEU less for profit, a more significant difference than in low markets. In high markets, rates range from $666/TEU to $625/TEU, where Suez Canal excels, needing $13-16/TEU less than COGH. This trend persists, emphasizing Suez Canal's advantage in high market conditions.

6.4 Research question 4

To execute the purpose of this research paper, the fourth research question has been presented as follows:

"Can any economies of scale benefits be identified?"

The interpretation of the data from the financial model can conclude that:

- The benefits of economies of scale can be identified across all market conditions based on vessel size. The larger the vessel, the better profit margin, lower load factor threshold as well as a higher tolerance to fluctuations in the spot market rates.
- The profit margins presented in the financial results show an increase in profit margins for all market conditions. However, we can identify that the larger vessels become more important in a lower market since the profitability sees an increase of 3,5 - 4,2 percentage-units when going from an 18.000 TEU vessel to a 25.000 TEU vessel. The increase is not as significant for the medium market condition where we see an increase of 2,7-3,1 percentage-units and for the high market, only 2,3 percentage-units for both the Suez Canal and COGH route.

6.5 Research question 5

To execute the purpose of this research paper, the fifth research question has been presented as follows:

Are the additional Red Sea surcharges used to cover costs, or increase profits?

Based on our judgement, we can conclude that:

- According to the analysis made, the report can conclude that container shipping companies have used the additional RSS as a way of increasing their profit, rather than applying a surcharge to cover the additional cost of circumnavigating COGH. Although the analysis made does not include general overhead or supply chain disruption associated costs, one can be led to believe that the increase in profits is far beyond the increase in costs, making the liner shipping companies use the RSS to increase profits, instead of covering costs.

7. RECOMMENDATIONS FOR FURTHER RESEARCH

Below are some of our main points and what further research are recommended to consider performing a similar report with accurate and satisfying results.

7.1 Different trading routes

The chosen trade route examined in this paper are one of many shipping routes worldwide. To apply this exact study may not be accurate to all alternative routings, but with some adjustment in sailing parameters, different trade routes could be analyzed in an economic context.

7.2 Different vessel sizes

Another result with smaller vessels would include a bigger sector of the shipping industry. Although this trading route are mainly trafficked by at least 18.000 TEU vessels, exceptions happen and the results arising from smaller vessels in the same financial model would be interesting to observe.

7.3 Eastbound leg or roundtrip calculations

Since this paper only focuses on the westbound leg, experimenting with the eastbound leg would be more accurate to the reality, and nonetheless an important metric to see. Defining load factor and spot market rates for the eastbound leg would be challenging since the trade patterns heavily differ from the westbound leg.

7.4 Redefining cost and income parameters

The cost and income parameters are an estimation made mainly from the reference paper but mixed with relevant cost and income parameters sourced from relevant papers and past experiences from the authors. For further research, one might include overhead costs, more precise capital expenditures, emissions costs etc. This will likely have a significant effect on the financial results.

7.5 Evolving the model building

This model is evolved from a former economic analysis that stem from an economy of scale perspective. Some sources had to be redefined to improve accuracy for this case. We encourage further research to be critical to our model and carefully collect relevant sources.

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