An Optimization Model for Strategic Decision Support in Maritime Transportation

Master Thesis

by

Stud. Techn. Jørgen Laake

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Supervisors:
Prof. Bjørn E. Asbjørnslett

Prof. Kjetil Fagerholt

Norwegian University of Science and Technology

Faculty of Engineering Science and Technology

Department of Marine Technology

NTNU

Faculty of Engineering Science and Technology
Department of Marine Technology

MASTER THESIS 2010
for
Stud. Techn. Jørgen Laake

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Strategic planning is an important part of carrying out a company's strategy. The shipping industry is known for its cyclical market behavior with abrupt fluctuations between market peaks and sloops. Conducting strategic planning under these conditions can appear as challenging because of the high level of uncertainty in future market predictions. Tools and methods that can help strategic planners to illuminate the consequence of their decisions and help them carrying out those decisions that will yield the highest profit will be valuable for ship-owners. These methods have yet to gain ground among the majority of tramp shipping operators and further research and development within this area is desired.

The candidate should address the following topics.

1. Give a brief outline of the shipping industry and its characteristic features.

2. Define strategic planning in maritime transportation and relate it to other levels of planning

3. Develop an optimization model that can be used as a decision support tool for ship-owners within tramp shipping. The model should be able to solve fleet size & mix problems, and evaluate contracts in the spot market. Emphasis should be put on developing a universal model that can be used on different problems.

4. Develop a test case in order to show the models different areas of application.

5. The candidate should learn and get familiarized with the optimization software Xpress IVE.

6. Implement the model in the optimization software Xpress IVE and apply the model to the case.

7. Based on the results from the case, it should be discussed to what extent such a model can be used in the industry.

8. Conclusions and recommendation for further work

Bjørn Egil Asbjørnslett
Professor, Marine Systems Design – Maritime Logistics

PREFACE

This report is an individual Master Thesis. The thesis is written at the Norwegian University of Science and Technology (NTNU) as a part of a 5 year profession study in Marin Technology with specialization in Marin Project Planning and Logistics. The thesis is the result of one semester of work extending from January to June 2010.

The aim of this master thesis is to develop an optimization model that can be used as a strategic decision support tool for shipowners. Initially the scope included developing both a deterministic and a stochastic optimization model. They were then to be run for a test case and the results would be compared to determine the preferred method. The scope was eventually downsized halfway in the process to cover the development and testing of a deterministic model.

It has been an ambitious goal set forth by the author to select this topic, which must be said to be somewhat off the mark of his educational field of specialization. Even though the original scope had to be redefined, the resulting optimization model presented in this master thesis has given valuable results as to its areas of use and applicability to different strategic decision problems.

Programming in a software one has never used before can sometimes feel like finding yourself in a foreign country where they only speak a language similar to nothing you have heard before. Then even simple tasks e.g., like asking for directions, become hard to overcome. In order to be able to achieve your goals you have to find your “Rosetta stone” and slowly learn the language.

My “Rosetta stone” has been various examples and small tutorials found in different user guides for the optimization software used, Xpress IVE, and the programming language Mosel. Learning Mosel was the easier part. Harder was there to figure out the “grammar” of Xpress. There seem to be as many ways to structure a model in Mosel as there is examples in the user guides. This makes it equally difficult to determine any good modeling practice or detect necessary language features needed to control and execute the model.

The learning process has mostly been based on trying to figure out how to use advanced language features. This was done by finding and comparing several example-models that contained the desired feature, but at the same time were different enough so one could use logically reason to determine how to use it to get the desired result. This has consequently been very time consuming. Especially frustrating has it been when the model has not behaved as expected or failed to function. Often without having the slightest idea of the underlying reason it has resulted in numerous hours being used to isolate and test each function of the model, hoping by that to detect and overcome the problem. It can without doubt be said that the author’s inexperience with the optimizer software has been a reason for the several months used on implementing the model. The risk of this being the outcome was known from the start, especially since it was clear that there were little to no knowledge at the Department of Marine Technology when it came to user experience with the optimizer software Xpress IVE.

The cases used to show some of the optimization model's areas of application could preferable have been more comprehensive when it comes to the length of the planning horizon. However, due to the late completion of the model implementation and the time consuming work of collecting and arranging input data, this was not achievable.

Special thanks will be given to persons contributing to the completion of this project. Professor Kjetil Fagerholt and Professor Bjørn Egil Asbjørnslett have been very supportive throughout the process. Siri Solem at DNV proNavis has contributed with essential knowledge concerning Xpress and has been an important source for completing this project.

A CD containing the thesis, the input data for cases and the Xpress model with input files and results is included.

Jørgen Laake, Trondheim, 11th of June 2010

ABSTRACT

Approximately 80% of the world trade measured in volume is carried at sea and there are accordingly many different actors making the shipping industry close to a perfect market. The shipping industry is also a highly volatile industry with abrupt market fluctuations. Under such premises correct timing of decisions becomes essential for those who want to succeed. The nature of the shipping industry also makes it difficult to conduct strategic planning because the fluctuations and irregular pattern between the cycles make the future hard to predict.

In this thesis an optimization model that can be used as a tool for strategic planners is presented. An introduction to the shipping industry is given in order to set the background for developing an optimization model. Different types of planning are discussed and important issues connected to strategic planning in shipping are addressed.

A deterministic optimization model is presented which suggest the strategic long term decisions that will yield the highest profit for a given planning period. It can be used to evaluate contracts up against each other and find the best mix of COAs and spot contracts for a given fleet, find the optimal fleet size & mix for a set of contracts or a mix of both. In that way it is a very flexible model that can be adapted to fit different scenarios, ranging from small fleets to the larger ones. The model can be used as a basis for a fleet renewal program, helping to decide when to sell and whether to buy old or new ships. It also takes into consideration the time charter market, recommending when to charter in vessels and when to charter out. Another area of application is for users that only are engaged in active vessel trading and not in transportation.

A fictional case is used to illustrate how the model can be used to help the management in a shipping company evaluate different strategies. Limitations related to the model and the uncertainties connected to using forecast data is discussed in the thesis.

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1 INTRODUCTION

1.1 MOTIVATION

How can we make decisions regarding the future while also knowing the consequences they will inflict? This is an essential question for all who are involved in strategic planning. For a shipowner this involves deciding when to buy and sell vessels and also which contracts to take on. The maritime industry is highly volatile when considering how abrupt the market fluctuations occur. Correct timing of decisions is essential in order to succeed. Being able to strategically positioning your shipping company in front of both market slopes and booms decides whether you can play the market better than you competitors and reap the reward. Strategic planning is a central key for staying on top of the game. Those who possess knowledge of methods that increases the possibility for succeeding in this and have the will to use them can gain a lead on their competitors.

This master thesis seeks to develop an optimization model that can be used as a strategic decision support tool for bulk operators. The objective should be to determine those decisions that lead to the highest profit achievable for a given planning horizon.

1.2 OUTLINE

This report is concerned with optimization models as a tool for strategic planners in shipping companies within the bulk segment. Part of this master thesis is concerned with developing such a model. Chapter 2 gives an introduction to the shipping industry and its players. Chapter 3 focuses on the different levels of planning within shipping. Emphasis is put on strategic planning and important issues related to this. The problem is introduced in Chapter 4 followed by a presentation of earlier solution approaches. In Chapter 5 the optimization model is presented and Chapter 6 encompasses three cases used to illustrate the model's area of applicability. The implementation of the model in the optimizer software is touched upon in Chapter 7 and in Chapter 8 the results from the three cases are presented and discussed. Further is the model's characteristics commented in Chapter 9. A concluding remark is made in Chapter 10 and Chapter 11 purposes suggestions for further work.

2 THE WORLD OF SHIPPING

This chapter aims to give the reader a brief introduction to the shipping industry. It focuses on special characteristics of the industry, the players and the market drivers in order to enlighten the necessity of strategic planning as a success factor. Chapter 2 and 3 is, if not specified otherwise, based on (Stopford, 2009)

2.1 THE OPERATORS

Approximately 80% of the world trade measured in volume is carried at sea (Fuglestvedt et al., 2008). This implies that there exists a huge market for overseas transportation and accordingly many shipping companies. The shipping companies can usually be defined into three categories; industrial shipping, tramp shipping and liner shipping (Lawrence, 1972). The industrial operators own the cargo and try to minimize the cost of transporting the cargo from A to B. Tramp shipping can be compared to the services of a taxi as they follow available cargo. They often have some long term Contracts of Affreightment (COA), and takes on additional spot cargoes as this becomes available in order to maximize the profit. Liner shipping operates in accordance to pre-published schedules and can by that be compared to the services of a bus.

2.2 SHIPPING RISK

There is, as in most businesses, a risk involved in shipping and investing in ships ties up large amounts of capital. As a comparison, a tanker can cost up to $150 million which is the same as a jumbo jet. Choosing the right timing for when to order new ships and when to scrap old ones requires a lot of skill and also luck. The demand and supply for different commodities are constantly changing. If there is a shortage for ships the rates will increase since the shippers will bid over each other in order to get their cargo transported. Otherwise warehouses will be stacked up, outlets will get sold out, steel mills will close in lack of iron ore and coking coal etc. When rates increase due to shortage of tonnage investors will see the opportunity to earn money and will order new ships. Then the rates will start leveling out as the newbuildings start arriving and eventually there also might be a surplus of ships available. This will again result in ships being laid up as a result of lack of cargo. Being able to act at the right time is essential in the shipping game but it is also attached large risk to this decisions. This risk is known as *the shipping risk.* If the shipper takes this risk he chooses a policy which we described earlier as industrial shipping, where he tries to minimize the transportation cost. If the shipowner takes on the risk we get a highly speculative market where the distance between periods of high rates and easy money quickly can be substituted by low rates and ships being laid up. These fluctuations are what we call shipping cycles.

2.3 THE SHIPPING CYCLES

The cycles exist to even out the balance between demand and supply and (Stopford, 2009) divides the cycle into four stages; *through, recovery, peak/plateau* and *collapse*. The *through* starts with a surplus of capacity and can be recognized by build-ups of congestion in ports and owners who start slow steaming their vessels. When surplus capacity becomes obvious in the market the rates starts to fall. Freight rates will first drop to the level of operating costs and then further below, resulting in a negative cash flow for shipowners. Shipowners with a low capital reserve are forced to start selling ships, which leads to a drop in second-hand prizes until it reaches the level of the scrapping price. The result is an active demolition market.

Recovery starts when the surplus is being absorbed and the market moves towards balance. The first signs can be seen as the rates increases to a level covering the operating costs and as a decrease in laid up tonnage. The market sentiment is still unsure and it is not possible to say for sure whether this is the start of an upturn or just a correction.

A peak/plateau emerges when all surplus capacity are absorbed. There is a tight balance between demand and supply, the rates are high and vessels are sailing at full speed. The prize of second-hand vessels increases to above "book value" and newbuildings can be sold for more than its newbuilding price. Banks are eager to syndicate loans and the order books start filling up.

The *collapse* is imminent when the newbuildings are delivered and a surplus of capacity re-emerges. Warning signs of a collapse are accumulation of idle spot ships in key ports, decreasing rates and the fact that the most unattractive ships must be laid up.

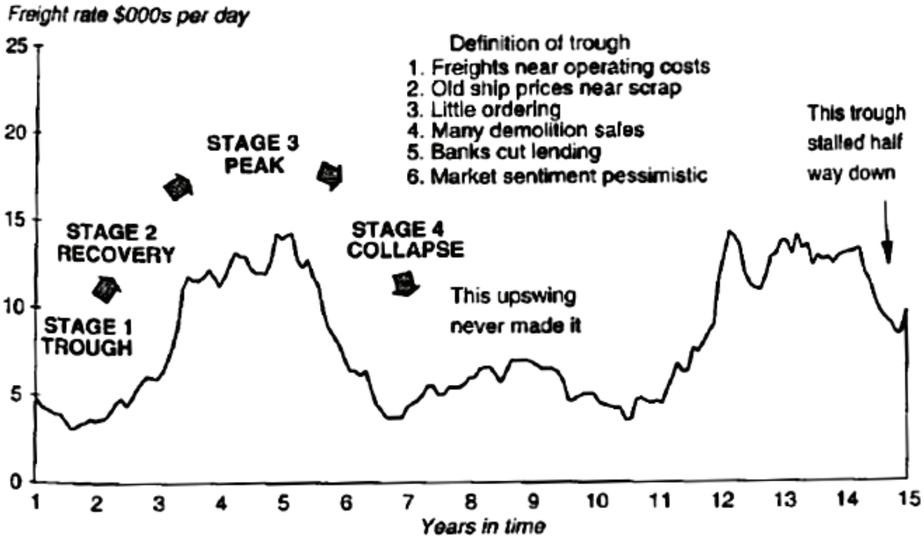

FIGURE 1 - STAGES IN A DRY MARKET CARGO CYCLE

Source: Martin Stopford, 2009

According to (Stopford, 2009) there is no regularity in when a new cycle starts and how long it will last. The only "cyclical" aspect is that each cycle seems to consist of the four stages mentioned previously. The duration of the stages can vary from weeks to years and are highly dependent on the market sentiment, as it can either accelerate or decelerate each stage. However, the triggers that initiates the different stages such as ordering newbuildings, scrapping old ships and economic conditions, seems to be the same for each cycle. These can to some certainty be analyzed and modeled, but in addition to this come the more uncertain factors.

The demand for overseas freight services is a derived demand caused by the unequal demand and supply of commodities between countries and continents. This worldwide market is subject to the influences of politics, wars and the development of the world economy, factors that can be near to impossible to model. In addition, some of the largest commodities are also subject to seasonal fluctuations (Kavussanos and Alizadeh-M, 2001). An example of this is grain which depends on each year's harvest. Has there been a good harvest in one part of the world, there would likely be an increase in the export of grain from these suppliers. Another example is thermal coal or oil. The demand for these commodities will vary with, among others, the winter seasons. Imports of these are likely to increase in countries experiencing a cold winter. Other commodities such as iron ore and coking coal tends to follow the world economy. Both are used in the production of iron and the demand for iron increases in periods of economical revival, when investments are done in growing industries. However, the demand decreases again with economic contraction and subsequent also the need for transportation of iron ore and coking coal.

Such fluctuations are due to circumstances that no operator can control. It may be possible to predict the development of the market on a short-term basis, but history has shown that long-term forecasts have a poor track record when they are compared with the real market development. What it all comes down to is to plan ahead so one is able to adapt to the market development and make the most of the opportunities that arises. Those who understand the cycles and has a realistic view of what is driving each stage while at the same time are able to see the signs of progress through the stages, are those who will prevail.

3 LEVELS OF PLANNING

"Failing to plan is planning to fail"

Alan Lakein, author

Planning is essential in order to succeed in the long run. Players that are only in the market with a short time horizon may be lucky and reap the reward of high rates of a current peak. However, a vessel's life time is approximately 20-25 years and can be considered to be a long time investment. As we see in Figure 2 there have been several cycles the last 25 years. For a long term player it is essential with proper planning in order to be able to handle the market fluctuations and survive.

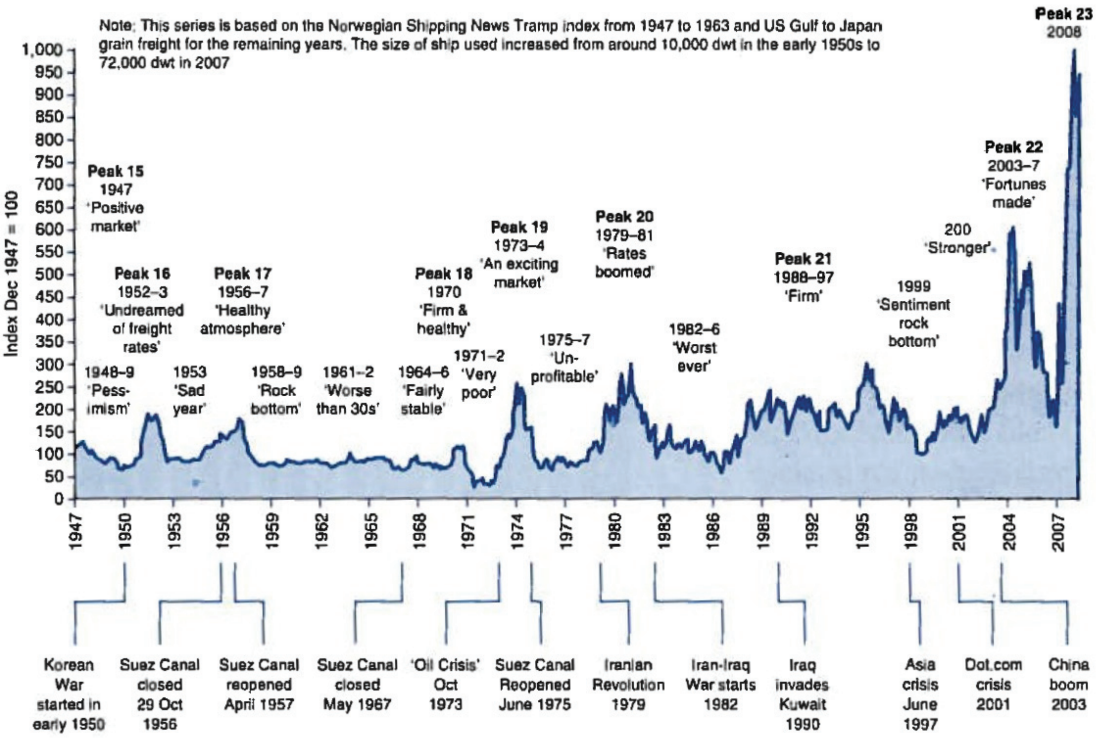

FIGURE 2 - CYCLES IN THE DRY BULK MARKET

Source: Martin Stopford, 2009

(Christiansen et al., 2007) classifies maritime transportation planning problems into three groups; *strategic, tactical* and *operational problems*. This thesis focuses on strategic problems. There is however, a strong interplay between strategic, tactical and operational planning since one often needs some tactical or even operational information in order to make strategic decisions. Therefore a description regarding each level will be given with emphasis on strategic planning.

Planning level	**Time horizon**	**Business problems**
Strategic	1 < years	• Market and trade selection • Evaluation of long-term COAs • Ship design • Fleet size and mix
Tactical	Weeks to months	• Assigning vessels to routes • Assigning cargo to vessels • Deciding whether to take on spot cargo • Deciding whether to use spot charters
Operational	1 day – couple of weeks	• Weather routing • Deciding cruising speed • Deciding where to refill bunker

TABLE 1 - LEVELS OF PLANNING

3.1 STRATEGIC PLANNING

Strategic planning covers a variety of different problems such as market and trade selection, ship design, network and transportation system design and fleet size & mix decisions. Common for all these are that the planning horizon spans from one to several years. As it has been described in the above chapters, the shipping risk is a made up by a complex composition of different factors which can be influenced by anything from the current world fleet capacity to unpredictable seasonal weather changes or vague psychological factors like the market sentiment. Due to the complexity of the shipping risk the market is highly volatile over time, which further complicates strategic decisions. For shipowners who desire a long existence with economic growth, strategic planning is essential in order to be able to handle shipping booms, slumps and steady markets.

One of the most important strategic decisions is the fleet size and the combination of different vessel types, known as the fleet size & mix problem. Another decision is what kind of contracts to enter into. This can be looked upon from two different angels; either that the contracts you choose to enter into determine how large the fleet must be or that the fleet determines which contracts you can enter into.

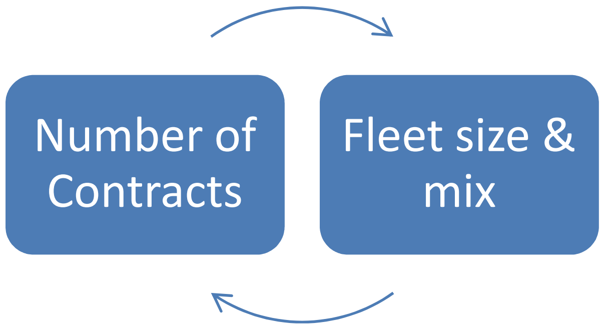

FIGURE 3 - RELATION BETWEEN CONTRACTS AND FLEET

3.1.1 CONTRACTS

There are different approaches depending on the shipowner's focus. When focusing on the contracts, the goal for a tramp shipping operator is to find the optimal split between long term contracts and spot cargo. This should be based on estimation of future rates and demands, even though this can be hard to predict. It also depends on the form of the contract or *charter-party*, a contract that sets out the terms between shipowner and charterer. There are several different charter-parties, differencing form each other in the way the risk and the costs are divided between shipowner and charterer. The four most common charter-parties are *voyage charter, contract of affreightment, time charter and bareboat charter* and a brief characteristic of each will be given below.

Voyage Charter
In a voyage charter the shipowner gets paid a freight rate for every unit of cargo he transports from A to B. The shipowner usually has to pay all costs except from possible cargo handling. The shipowner is also responsible for manning the vessel, managing the ship and planning the voyage. Under a voyage charter agreement the shipowner takes both the operational and the market risk. The financial burden is solely upon the shipowner if there should be e.g. a lack of cargo to be transported or if the ship should break down.

The Contract of Affreightment
The contract of affreightment (COA) is the most common long-term contract in tramp shipping (Fagerholt et al., 2010) and can be described as a contract where a shipowner agrees to transport the goods belonging to one or many goods owners for a fixed price per ton. The charterer's interest lies in getting the cargo from A to B and leaves the shipowner to plan the voyage. This enables the shipowner to choose which vessels to be used, which again opens for a

better utilization of the fleet e.g. by arranging a backhaul cargo. The most common problem with negotiating a COA is that the precise timing of the cargo shipments and its volume is seldom known in advance. It is therefore common to specify the cargo volume with a lower and upper boundary. The timing can also be arranged by specifying that the shipments under the contract should be spread out evenly over the contract period. The fact that the cargo amount can vary, represent an element of uncertainty for the shipowner when it comes to scheduling cargo to the vessels. Another aspect is that when rates are low, the charterer will only send the lower boundary with the shipping company engaged in the COA while using spot charterers to transport the rest for a lower rate.

Time Charter

A time charter hire involves that the shipowner gets paid a fixed daily or monthly amount by the charterer. The charter period can vary from a single voyage (trip charter) to several months or years (period charter). The charterer pays for the voyage related costs such as fuel, harbor and canal fees and cargo handling costs. The shipowner pays the operational expenditures (OPEX) and takes the operational risk, i.e. he has to pay if the ship breaks down. However, the market risk is now covered by the charterer who has committed himself to pay the fixed amount regardless of how the market develops.

Bare Boat Charter

Bareboat charter involves that the charterer takes over the full control over the vessel and its expenses. This is often done when an investor, which can be a financial institution that lacks the knowledge of operating a ship, buys a vessel and then bare boat charter the vessel out to a shipping company. The advantage is that the shipping company can avoid tying up capital and the owner can obtain tax benefits.

Different shipping companies have different strategies and risk profiles and these can be reflected in the type of charter-parties the companies are engaged in. A voyage charter exposes the shipowner to both the operational risk and the market risk. On the other hand, it gives the shipowner the opportunity to grasp the full benefits of a high-rate market. A COA is a more stabile income source since the COA rates will be less volatile than the voyage charter rates. This is because a COA usually has duration of several years and the price is fixed for the duration of the COA. A time charter moves the market risk from the shipowner and over to the charterer in the same way as a COA, but the shipowner loses the possibility to better utilize the vessels when the operational control is left with the charterer. Finally, when a company wishes to have full control over a vessel but doesn't want to be the owner, a bareboat charter is arranged.

A good charter-party ensures that it is clarified whom that is legally responsible if one of the parts fails to fulfill the terms in the charter-party. This could be late arrival of cargo due to bad weather, port congestion or a port strike. Because it is time consuming to set up a new charter-party for every contract, especially voyage charters, it is developed standards that are used by the shipping companies. One of these is the BIMCO 'Gencon'. It consist of two parts and (Stopford, 2009) outlines the principal sections in this charter-party and divide them into six major components as follows:

1. *Details of the ship and the contracting parties. The charter-party specifies:*
    - *The name of the shipowner/charterer and broker;*
    - *Details of the ship – including its name, size and cargo capacity;*
    - *The ship's position;*
    - *The brokerage fee, stating who is to pay.*

2. *A description of cargo to be carried, drawing attention to any special features. The name and address of the shipper is also given, so that the shipowner knows whom to contact when he arrives at the port to load cargo.*

3. *The terms on which the cargo is to be carried. This important part of the voyage charter-party defines the commitments of the shipper and shipowner under the contract. This covers:*
    - *The dates on which the vessel will be available for loading;*
    - *The loading port or area (e.g. US Gulf)*
    - *The discharging port including details of multi port discharge where appropriate;*
    - *Laytime, i.e. time allowed for loading and discharge of cargo;*
    - *Demurrage rate per day in US dollars;*
    - *Payment of loading and discharge expenses.*

    If loading or discharge is not completed within the time specified the shipowner will be entitled to the payment of liquidated damages (demurrage) and the amount per day is specified in the charter party (e.g. $5,000/day).

4. *The terms of payment. This is important because very large sums of money are involved. The charter-party will specify:*
    - *The freight to be paid;*
    - *The terms on which payment is to be made;*

    There is no set rule about this – payments may be made in advance, on discharge of cargo or as installments during the tenure of the contract. Currency and payment details are also specified.

5. *Penalties for non-performance – the notes in Part 2 contain clauses setting out the terms on which penalties will be payable, in the event of either party failing to discharge its responsibilities.*

6. *Administrative clauses, covering matters that may give rise to difficulties if not clarified in advance. These include the appointment of agents and stevedores, bills of lading, provisions for dealing with strikes, wars, ice, etc.*

3.1.2 *Fleet Size & Mix*

Fleet size & mix problems seek to determine an optimal fleet for a given market situation. It is not very often that one has to determine a whole new fleet. Often adjustments to an existing fleet are sufficient. Needs for adjustment can arise because vessels have to be sold or scrapped or because new COAs has been taken on.

Deciding the optimal fleet size & mix may be done relatively simple in theory, but capital is necessary to realize the optimal result. Therefore, capital cost constraints will in most cases be present when applying optimization models to fleet size & mix problems.

Capital cost appears in two stages. The first stage is as purchase price of the ship. These will in most cases include a brokerage or commission cost and often also an inspection/survey cost. There is a difference between the newbuilding price and that of a second-hand vessel. While the price of a newbuilding depends on berth capacity at the yards, and thereby is a function of the world demand for newbuildings, the second-hand price is directly related to the demand and supply in each shipping segment. One can say that the second-hand price reflects the current opportunities and sentiment for each segment. Although the newbuilding price will vary with the size and complexity of the vessel, it will be generally high for all kind of vessel types and sizes in a strong market and low when the order books are near to blank. This can be illustrated in Figure 4, where there is a significant drop in newbuilding prices following the collapse in 1973 and 1979.

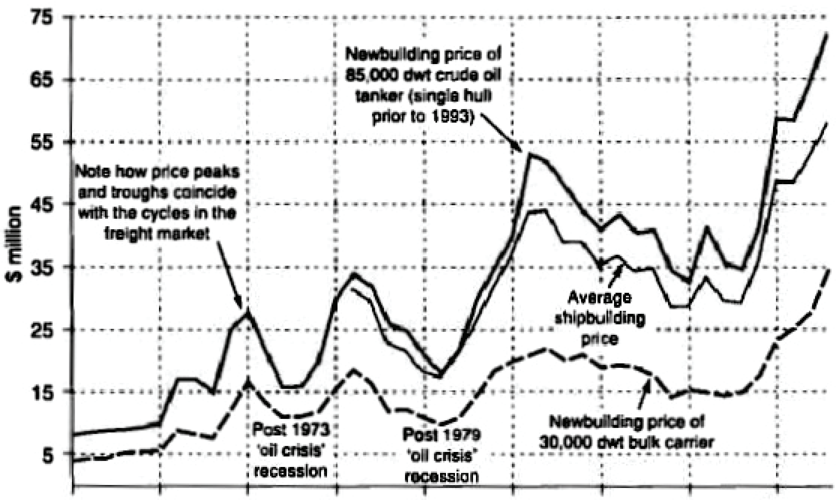

Figure 4 - World shipbuilding prices, 1964-2007

Source: Martin Stopford, 2009

The second stage where capital appears is as cash payments to banks or equity investors who put up capital to purchase the vessel. This brings us over to the different methods of acquiring the necessary capital for an investment in a ship. This is not covered by the model but since deciding the method for financing new vessels is an important strategic decision and since the type of financing method chosen often can be related to different types of shipowners, some of the most common methods will be briefly outlined in the following section. If not specified otherwise, the information in the following section is gathered from (Stopford, 2009).

3.1.2.1 Methods of Financing

When a shipowner or a shipping company is to acquire a new vessel they have to evaluate several methods of financing. Large shipping company that has sufficient capital reserves or high cashflow can use this as finance. Smaller companies must seek other sources, such as private investors or commercial banks.

The main focus of investors is on the upside of an investment since they take risk for profit. The lenders have the opposite view since they don't share the profit. For them, the focus is on the possible downside of an investment since this can affect the borrower's ability to repay. With shipping being such a volatile market the hardest problem for shipowners is to convince the lenders that the investment of buying a new ship is sound and that there exist a sufficient security for the loan if the investment should turn out not to be profitable.

In the business the term 'shipowner' and 'shipping company' is used interchangeably, but when it comes to discussing different methods of financing ships we have to define them more precisely.

> *A shipowner is an individual who owns a controlling interest in one or more ships* (Stopford, 2009).

The structure is usually laid out as a one-ship company, where the shipowner has the controlling interest. Other assets and cash are preferably held separate in bank accounts in tax-beneficial locations. The day-to-day operations are handled by an agency or management company, creating a non-transparent structure for third parties. This is beneficial for the shipowner because liabilities related to the ship cannot be transferred to other one-ship companies controlled by the shipowner. E.g. if one such one-ship company should go bankrupt the shipowner can by arranging his vessels in one-ship structure companies hedge the rest of his vessels against taking on the liability that follows the bankruptcy. However, because of the non-transparent company structure the shipowner and agency must establish creditworthiness in order to trade. Since there is no easy way for third parties to get this confirmed a good name is of high importance for such shipowners.

> *A shipping company is a legal organization which owns ships. It may be a legal partnership, company or corporation in a jurisdiction with enforceable laws of corporate governance, with an audited balance sheet showing its controlling interest in the ships it operates and*

the status of its other assets, liabilities and bank accounts. It's executive officers are responsible for running the business and taking investment decisions (Stopford, 2009).

The difference of the two can be seen clearly in Figure 5.

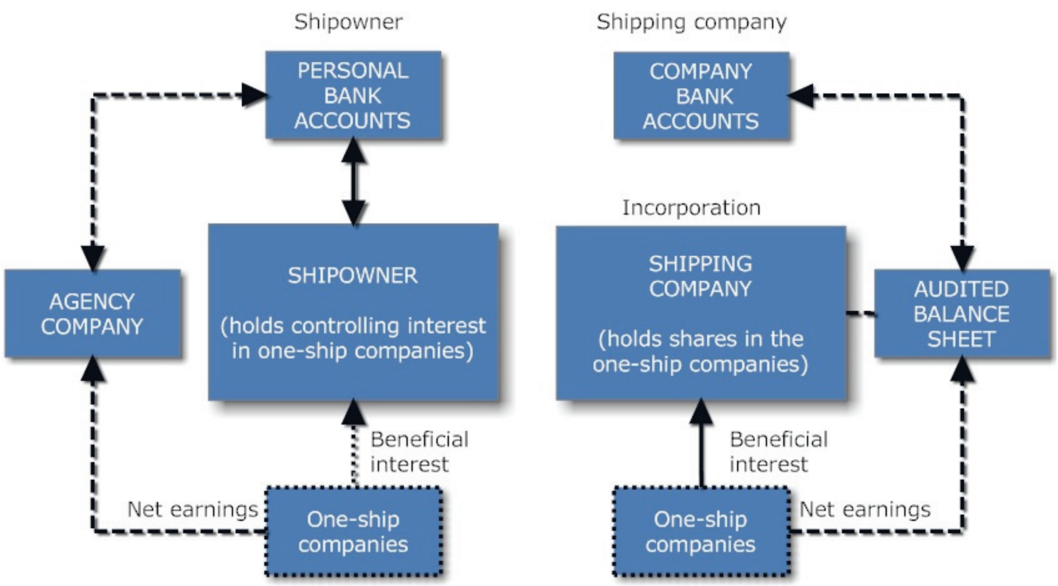

FIGURE 5 - DEFINITION OF SHIPOWNER AND SHIPPING COMPANY

Source: Martin Stopford, 2009

Private Funds

When buying a vessel the most natural is to use private funds, either generated through the income of other owned vessels, through capital reserves or by equity or loans from friends, relatives and venture capitalists. The benefit of lending from family or friends that is familiar with the shipping business is that they are more likely to understand the cycles in the market and how this has a volatile effect on the return. This is often also the only way to acquire the necessary capital for start-up businesses.

Bank Finance

Loans from banks is the major source for financing ships and is the most important way for shipowners and shipping companies to get the capital they need. For shipowners there are three main types of loans available. These are *mortgage-backed loans*, *corporate loans* and *shipyard credit scheme loans.* This type of loans has some limitations. As a bank only is willing to advance a limiting amount, large loans must be syndicated among several banks. Another limitation is that such loans usually are restricted to a period of 5-7 years and that the advance rate is of 70-80%.

A mortgage-backed loan gives the bank security in the value of the ship. This is in particular good for one-ship companies. Since they don't have audited accounts the bank cannot check their creditworthiness. But by taking security in the ship a bank can give loans to one-ship companies if they find the risk acceptable.

While mortgage-backed loans are favorable for shipowners, it will be inconvenient for large shipping companies to borrow against individual vessels because an adjustment to the fleet composition would imply time-consuming loan transactions. Therefore shipping companies takes loans with their balance sheets as collateral. This is a flexible source for income allowing for unplanned purchases or cashflow fluctuations. If the loan is large the bank will not be able (or willing) to take it on alone and large loans are usually syndicated among several banks.

Financing newbuildings are quite similar to acquisition of second-hand vessels, but there are two differences that makes this a bit more complicated. First, the capital cost of a newbuilding is generally too high compared to the profit it will gain on the spot marked. This means that one cannot use cashflow to finance the newbuilding, especially if the loan is given for a period of 5-7 years. Also, unless a time charter is prearranged for the newbuilding it will be difficult, especially for one-ship companies, to provide sufficient security. Secondly, since the loan must be issued before the building commence, there will be a period where the hull is not available as collateral.

A shipyard usually requires stage payments, as they have running expenses related to materials and labour. At each stage roughly the same amount is paid to the shipyard, with the final stage being delivery. There is a risk that even though the stage payments are made, the ship will not be finished. This can be due to the shipyard going bankrupt, technical errors or political instability in the country where the shipyard lies. This risk is usually covered by a 'refund guarantee' supplied by the shipyard's bank. A shipyard credit is given in many countries by their respective governments to assist their shipyards in obtaining orders. This can be done e.g. by issuing a government guarantee, which is a subsidy of the yard since it gives better terms than is obtainable form a commercial bank.

Capital Markets

There is two ways to raise finance for financing vessels on the capital markets. The first is to offer stocks against public equity on a stock exchange. A description of the necessary process for a company that wants to be able to offer public stock will not be given here, but can be found in (Stopford, 2009).

The other possibility is to issue bonds. A bond is a debt security that is sold by the bond issuer (shipping company) to the bondholder (a financial institution). The bond issuer is committed to buy back the bond on a specific date, say in a 10 years' time. Meanwhile the bond issuer pays interest to the bond holder. The use of bonds provides large shipping companies, which have good relations to financial institutions, with a quick and easy way of raising capital.

Special Purpose Companies

Special purpose companies (SPCs) buys the ship, appoint a manager to operate it and then they time-charter or leases it out. Such companies have a special structure designed for equity investors to invest in shipping. Examples of such structures are ship funds, Norwegian K/S partnerships and German KS funds. For an elaboration of each structure, please see (Stopford, 2009).

3.1.3 Revenue and Costs

The revenue depends on the cargo capacity, the number of different vessel types and the number of each vessel type a shipowner has. It also depends on the form of the charter-parties as they will determine the freight rate. A COA provides a steady income while a voyage charter relies on the spot freight rates. The latter will be a benefit during market booms but can be a financial burden during sloops e.g., if the operating costs are higher than the freight rate. The costs will vary with each vessels characteristics e.g. fuel consumption, maintenance, crew etc. It will also vary with the route (distance). A shipping company's mix of different types of charter parties will depend on each shipping company's risk profile and strategy but in general charter parties is chosen based on expected revenue. It shall also be mentioned that taking on a contract sometimes also can be a question of market share and strategic positioning, not only a question of expected profit and capacity. The challenge lies in making decisions that maximize the profit.

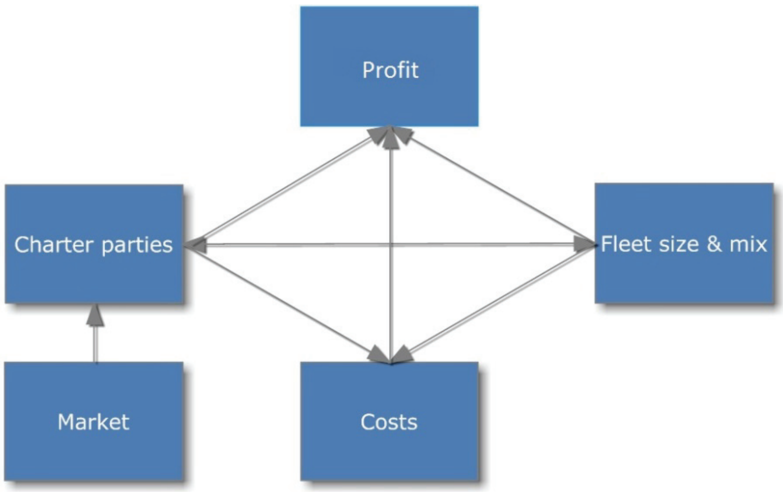

Figure 6 - Factors affecting the profit

Operating Cost
The operating cost covers the categories over which the shipowner or manager has the most control. These are *manning cost, stores and supplies, repairs and maintenance, insurance* and *administration.* The operating cost can be described as day-to-day expenses that are needed in order to keep the vessel operative. This excludes fuel, which is included in voyage cost and major dry dockings which falls under the periodic maintenance post.

Manning costs is the largest post under operating cost. *Manning cost* varies with the size of the ship, the degree of atomization of the ships systems and the amount of on-board maintenance undertaken.

Stores and supplies is not one of the major posts on the operating cost budget, but it's covering general stores such as spare parts and deck and engine room equipment. Cabin stores, water and lubricants are also part of this post, with the latter being the largest expenditure.

Repairs and maintenance covers all work that is necessary in order to maintain the required standard set by the classification society. This includes mainly routine maintenance but can also involve cost in connection with breakdowns, if they can be fixed on-board. The degree of on-board maintenance tends to increase in accordance to the vessels age.

Periodic Maintenance

Periodic maintenance is performed on regularly basis in order to maintain the class approval. This is done in dry-dock and the interval is normally 2,5 year for merchant vessels if the ship is older than 10 years. Upon delivery of a new vessel it is normal to have two 5 year intervals. During such a maintenance session all machinery and relevant systems are inspected and all deficiencies must be repaired in order to have class reapproved. It is quite expensive to have a vessel in dry-dock since one has to take the vessel out of service. Therefore, a proper survey of the vessel while it is sailing should be done. This will provide an overview of necessary work to be carried out, enabling the owner to plan upfront the work to be conducted in dry-dock. Consequently the time spent in the dry dock will be reduced and accordingly also the costs.

Voyage Cost

The voyage costs consist of fuel cost, harbor fees, fees for tugs and pilotage and canal dues (if there are canals on the route). The costs will vary both with the voyage and the size of the vessel. Fuel cost is a function of the engine speed and efficiency, hull resistance, propeller efficiency and amount of cargo. An older vessel is likely to have a less efficient engine than a newer, more modern vessel. Also the degree of marine growth on the hull will affect the fuel consumption.

The amount of money invested in measures to reduce the fuel consumption tends to increase with an increasing fuel price. This was the scenario during the 70's when fuel prices were rocketing and much effort was laid down to improve the efficiency of machinery and hull. We can now see some of the same tendency as a result of increased focus on reducing emissions from ships. With the ongoing discussion in IMO on how to reduce CO_2 emissions, it may only be a matter of time before CO_2 emissions will be taxed either by the form of quotas or a levy. Since the amount of CO_2 produced is directly related to the amount of fuel burned, it can be looked upon as an increase in the fuel prices.

Costs and Age

As a vessel ages the capital cost reduces. However, there is an increasing need for maintenance when a ship gets older, as illustrated in Figure 7. We also see that the operating costs and voyage costs are lower for new ships because of newer and more efficient technology. If we don't consider the capital cost, we see that a new ship is a lot less expensive to operate than older vessels. This is an important consideration to take into mind when deciding whether to buy new or old vessels.

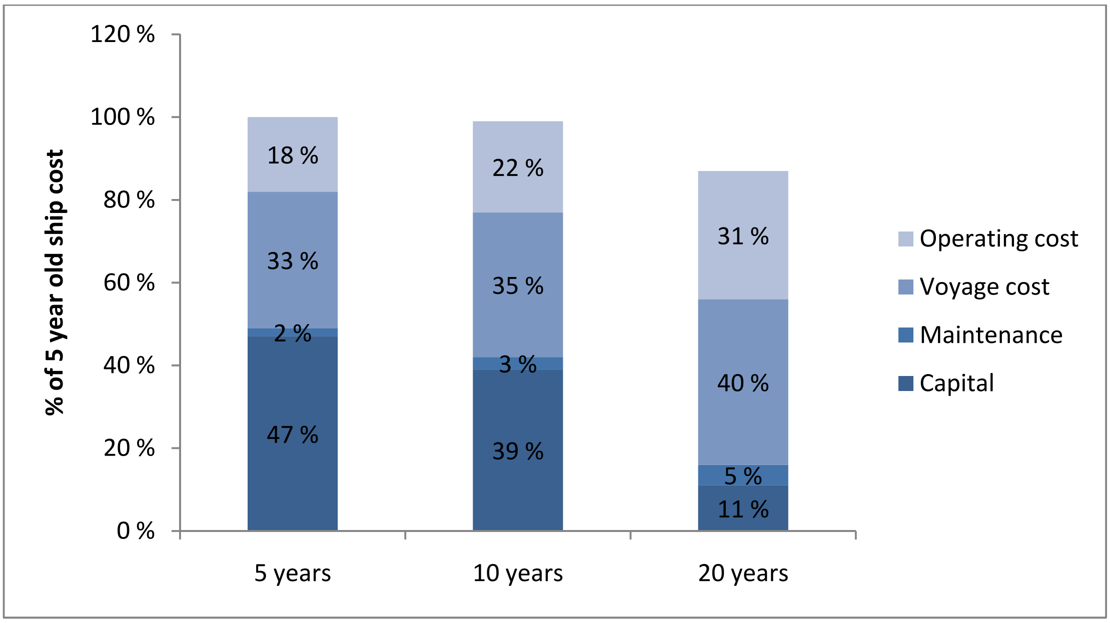

FIGURE 7 - CAPESIZE BULK CARRIER COST AND AGE

Source: Martin Stopford, 2009

3.2 TACTICAL PLANNING

Tactical planning relates to medium-term decisions such as routing and scheduling. This involves the decisions of which vessels should be assigned to the different cargos and in what sequence the vessels are visiting the different ports. Questions that usually arise are such as;

- Does the nature of the different cargoes allow them to be transported in the same vessel?
- Is the destination the same for all cargoes?
- and if not, does service speed and route selection allow for delivery of all cargoes at their specified destination within the time windows of each COA?

Tactical planning has a time horizon that reflects the visibility in the market and will usually vary from weeks to months. In tramp shipping the objective is to maximize the profit while servicing all COAs. Meanwhile, there can be spot cargo available in the market that represents an opportunity to increase the profit. The decision of whether to take on additional spot cargo or not is also taken with regards to the tactical factors mentioned above. For a more detailed description of short-term routing and scheduling problems, including mathematical models, reference is made to (Christiansen et al., 2007).

3.3 Operational Planning

According to (Christiansen et al., 2007) operational planning is used when there is high uncertainty in the operational environment or when decisions only have a short-term impact. Sometimes there is impractical to plan for more than one voyage. This can be if there is high uncertainty related to the demand and/or supply e.g. seasonal commodities. An example of a operational scheduling problem can be found in (Ronen, 1986). Environmental routing and speed selection also falls under the operational planning category.

Environmental routing or weather routing tries to find the shortest/best route by assessing the weather forecast for the given route. Bad weather can delay a vessel and in worst case inflict serious damage to cargo and hull. It is often considered wiser to sail around an area if the weather is so bad that you are running a high risk of inflicting damage to the cargo or the vessel.

Some shipowners choose to slow steam their vessels. This can be due to many different reasons but the underlying objective is to save money as reducing the speed by 20% reduces the fuel consumption with 50% (Ronen, 1982). An example could be that a vessel is on a ballast leg and don't have any contract in the upcoming port or that there is a period of very high fuel prizes. The latter was the issue when (Ronen, 1982), in the wake of the high fuel prices during the 1970s presented three models for determining the optimal speed for different type of legs. The fact that bunker prices vary from port to port, as we see in Figure 8, makes the choice of where to refill bunker an important one. In some cases it may be cost-beneficial to visit a port just to refill bunker even without loading/unloading cargo. Other issues that can affect the speed are delays caused by port congestion, tides or restricted opening hours in ports.

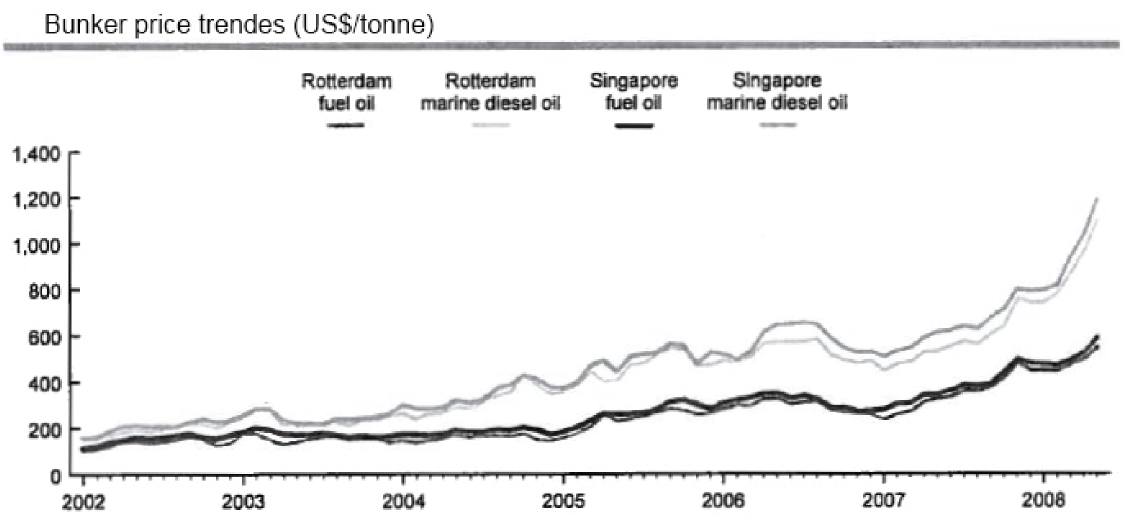

Figure 8 - Geographical variations in bunker price

Source: Drewry

4 PROBLEM DESCRIPTION

As we have seen there are many problems to address for a shipowner. This can be further illustrated by a small example as shown Figure 9. A shipowner has two long-term COAs; one involves transporting coking coal from Australia to Brazil and the other transporting iron ore from Australia to China. The shipowner owns three vessels where two are committed to transporting coking coal and the last to transporting iron ore. The total fleet capacity is then utilized.

However, there is also spot cargo available in the form of thermal coal from China to Japan. This leaves the shipowner with several issues to address. A shipowner involved in tramp shipping usually has a mix of COAs and spot contracts and since the fleet capacity is fully utilized there is no flexibility in the fleet to make the most out of periods with high spot rates. There are however several approaches for the shipowner if he wants to engage in the spot market. He can time charter vessels and use them to serve some of a COA and then free one or more vessel to service spot cargo or he can use the time charter vessels to take on the spot cargo. This will of course depend on the freight rates for servicing spot cargo being higher than the expenditures of using a time charter to service part of the COA.

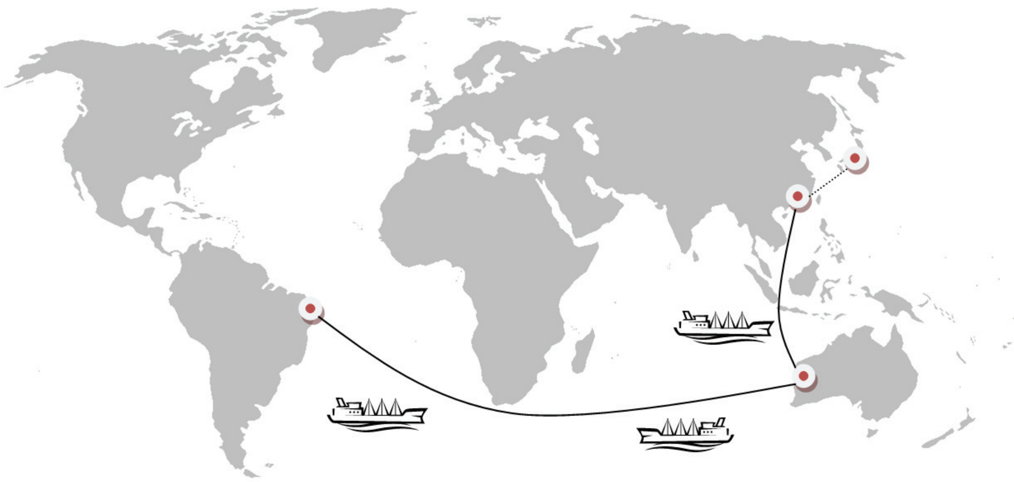

FIGURE 9 - PROBLEM EXAMPLE

Another possibility is to buy either a secondhand vessel or ordering a new vessel. The advantages of buying a secondhand vessel is that the vessel is ready to be put into service within a relative short period of time in comparison to a newbuilding that takes several years, depending on the complexity of the ship and the yard building it. The disadvantages can be that an older vessel will be less attractive when rates are low, depending on the vessels age and state. A new vessel will often be more fuel efficient due to newer technology and will thereby also have a lower operating cost. As it is very difficult to guess how the rates will develop over several years, ordering a newbuilding often is more of a gamble unless you have a long term contract to service.

There are two different angels of approach when conducting strategic planning, depending on the characteristics of a shipowner. Either the number of COAs you have committed yourself to decides the size of the fleet or the fleet size decides the number of COAs you can enter into. If a shipowner does not have enough capital or are not able to get a loan in order to expand the fleet, he must plan with the fleet size as the decisive factor for which COAs he can enter into. On the other hand, if the required capital is available, planning can be conducted based on the availability of COAs in the market and the profit of these. In this illustrative example there are just two COAs and three vessels but the options are already many. For a case where the fleet is substantially larger and the number of COAs much higher, the strategic planning process becomes increasingly more complex.

More often than not will the fleet be heterogeneous i.e. consist of several different vessel types. Since parameters such as the cargo capacity, speed, operational cost etc. varies with the size of the vessel and the fact that some routes also have size constraints (e.g. the Suez Canal and the Panama Canal) makes some vessel types more suitable than others on specific routes. The optimal fleet mix will vary from case to case all depending on what kind of COAs the owner has committed himself to service.

Strategic planning is not just about when to acquire more fleet capacity, but also when to reduce or go “short of tonnage”. This can either be done by selling vessels or scrapping them. Deciding when to scrap or sell vessels is not only dependent on the rates at that given time, but also on the duration of the COAs already engaged in. Deciding to scrap when committed to a COA may prove to be an expensive gamble if you have to use spot charters to cover for the scrapped vessel, for then only to realize that the rates starts increasing. This should be taken into consideration if the need for scrapping is not imminent. This leads us back to the option of using time charters if the fleet is not sufficient to service all COAs or to charter out some vessels if one is not able to fully utilize the whole fleet. A shipowner will typically go for as many COAs as possible if he thinks there will be low spot rates and the opposite if he believes spot rates will be high. How much of the fleet capacity that should be covered by COAs and how much that should be open for spot cargoes is consequently an important strategic decision.

This all boils down to what is deemed to be most profitable and the solution will vary from shipowner to shipowner depending on how high risk they are willing to take. Fleet size & mix decisions are closely interwoven with the decisions of which contracts to enter into and these should be evaluated together in order to ensure the most robust solution.

4.1 Solution Approaches

When deciding the optimal fleet size and mix, the underlying operational planning structure must be considered. This means that the routing problem often must be decided first. There are different ways to do this. One that has been used to solve several maritime transportation problems is to develop optimization-based models, e.g. mixed integer programming models. An example of this can be found in (Fagerholt and Lindstad, 2000). Such an approach can result in a very complex model since one usually includes details about the routing and scheduling aspects of the problem. The challenge lies in simplifying the problem. If not the models become so complex that only parts of the problem can be solved to optimality. This also results in the model only being applicable for one specified problem and thereby lacking a universal applicability for general strategic decision support problems.

Another approach is to use optimization-methods to solve the underlying routing and scheduling problems. Strategic decisions such as the fleet size or number of contracts are specified as parameters and different changes are made to the parameters and the results are analyzed. Specific cases are constructed to represent future developments in the market and the various possible outcomes. Historic and/or forecast data are used as basis when constructing these cases. The cases are then analyzed one by one and the results compared. A version of this approach was used in the pioneering work of Dantzig and Fulkerson (1954). The analysis are typically conducted for a much longer planning period than the periods that are used for real short-term routing and scheduling problems. By using complete information, such as planning short-term routing and scheduling beyond the market visibility, it can result in overfitted solutions. Another drawback is that the uncertainties in the problem are not handled very well. The result will then most likely be a better solution than what is achievable in real life.

A third approach is to use simulation. Some examples where simulation models have been used for strategic planning problems in shipping are (Darzentas and Spyrou, 1996) and (Richetta and Larson, 1997). This method is able to handle the stochastic aspects properly while it has some shortcomings as the routing and scheduling decisions often must be simplified or even dropped. The solution to this has been to combine optimization and simulation. This is done by (Fagerholt et al., 2010) where a Monte Carlo simulation framework is built around an optimization-based decision support system for short term scheduling. This allows for dealing with stochastic aspects while at the same time considering the underlying routing and scheduling aspects of the problem. However, since the model has omitted the spot market it is not applicable for tramp shipping companies that also operate within this market.

5 THE MODEL

This chapter presents an optimization model developed to solve the problem presented in Chapter 4. The model is created as a strategic decision support tool to help tramp shipping operators make the strategic long term decisions that will yield the highest profit for a given planning period. It can be used to evaluate contracts up against each other and find the best mix of COAs and spot contracts for a given fleet, find the optimal fleet size & mix for a set of contracts or a mix of both. In that way it is a very flexible model that can be adapted to fit different scenarios, ranging from small fleets to the larger ones. The model can be used as a basis for a fleet renewal program, helping to decide when to sell and whether to buy old or new ships. It also takes into consideration the time charter market, recommending when to charter in vessels and when to charter out.

5.1 SETS

We begin by defining all sets and indices. Let T be a set of periods, e.g., 1, 5 or 10 years. All decisions are made at the start of each period. This means e.g. if one decides to sell a vessel in period t, that vessel will no longer be part of the fleet in period t . Let N^{COA} be a set of different COAs available and N^{SPOT} a set of available spot contracts. For predefined contracts that the company already is committed to, the binary variable δ_i can easily be set to 1 to ensure selection of these.

Let V be a set of vessel types. This can be e.g. Handymax, Panamax and Capesize. Further let T_v be the time period connected to each vessel type, being the lesser of time periods left of the vessel type's lifetime or the number of periods in the planning horizon. Finally, let R_v be a set of predefined routes.

Set	Index	Description
T	t	*Amount of time periods,* $T = \{0,1,2,\ldots,T^{MAX}\}$*, where period* 0 *corresponds to the time period when the planning is done and* T^{MAX} *is the number of time periods considered. All decisions are made at the start of each period.*
N^{COA}	i	*Available contracts of affreightment*
N^{SPOT}	i	*Available spot cargo contracts*
V	v	*Available vessel types. Each type* v *also includes information of in which period a vessel was acquired,* t_v*, and its maximum lifetime,* T_v^{LT}*. Two vessels acquired in different years, but similar in all other ways will then have different indices.*
V^E	v	*Set of vessels in the existing fleet*
T_v	t_v	*Time periods for vessel type* v*,* $T_v = \{t_v, \ldots \min\{t_v + T_v^{LT}, T^{MAX}\}\}$ *, where* T_v^{LT} *is the number of time periods that corresponds to the vessel's lifetime.*
R_v	r	*Available sailing routes for vessel type* v

TABLE 2 - SETS AND INDICES

5.2 PARAMETERS

Let R_i^{COA} be the revenue of servicing contract i. T_{vr} is the time vessel type v uses to complete a roundtrip on route r and T_{vt}^{TOT} are the available operational days of vessel type v for period t. Q_{it} is the demand stated in COA i in period t and S_{it} is the available amount of spot cargo in spot contract i in period t. Q_v is the cargo capacity of vessel type v while A_{ivr} is a binary parameter that is 1 if cargo from COA i is serviced by vessel type v on route r and 0 otherwise.

Parameter	Description	Unit
T_{vr}	*Time for vessel type* v *to complete one roundtrip on route* r	Days
T_{vt}^{TOT}	*Total available time for vessel type* v *in period* t	Days
T_v^{LT}	*Maximum lifetime of vessel type* v *acquired in time period* t_v	*Periods*
Q_{it}	*Demand in COA* i *in period* t	Ton

Q_v	Capacity of vessel type v	Ton
S_{it}	*Upper limit of demand for spot contract i in period t*	Ton
A_{ivr}	*Binary parameter equal to 1 if route r for vessel type v includes COA/Spot i*	-
R_i^{COA}	*Revenue of servicing COA i*	USD
R_{it}^{SPOT}	*Revenue per unit transported of spot trade i in period t*	USD/ton
R_{vt}^{S}	*Revenue of selling vessel type v in period t*	USD
R_{vt}^{TC}	*Revenue of time chartering out vessel type v in period t*	USD
C_{vr}	*Voyage cost of sailing route r with vessel type v*	USD
C_{vt}^{I}	*Cost of buying vessel type v in period t*	USD
C_{vt}^{N}	*Cost of ordering newbuilding of type v in period t*	USD
C_{vt}^{TC}	*Cost of time chartering in vessel type v in period t*	USD
C_{vt}^{O}	*OPEX for a vessel of type v in period t*	USD
C_{vt}^{C}	*CAPEX for a vessel of type v in period t*	USD
N_{it}	*Minimum number of sailings servicing contract i in period t*	-
L	*Percentage of vessels acquisition price that are taken as a loan*	%
I	*Rate of interest on loan per period*	%
D	*Rate of depreciation of vessels per period*	%

TABLE 3 - PARAMETERS

5.3 VARIABLES

Decision variable	Description
y_{vt}^{TOT}	*Total number of vessels of type v operated in period t*
y_{vt}^{OWN}	*Number of vessels of type v owned in period t*
y_{vt}^{TCin}	*Number of vessels of type v that are time chartered into the fleet in period t*
y_{vt}^{TCout}	*Number of vessels of type v that are time chartered out in period t*
y_{vt}^{I}	*Number of vessels of type v acquired in period t*
y_{vt}^{N}	*Number of newbuildings of type v ordered in period t*

y_{vt}^{S}	*Number of vessels of type v that are sold in period t*
δ_i	*A binary variable that is 1 if COA i is selected and 0 otherwise*
x_{vrt}	*Number of roundtrips made by vessel type v on route r in period t*
z_{it}	*Quantity transported on spot trade i in period t*

TABLE 4 - VARIABLES

5.4 OBJECTIVE FUNCTION

$$\begin{aligned}
\max z = & \sum_{i \in N^{COA}} R_i^{COA} \delta_i + \sum_{i \in N^{SPOT}} \sum_{t \in T} R_{it}^{SPOT} z_{it} \\
& + \sum_{v \in V} \sum_{t \in T} R_{vt}^{TC} y_{vt}^{TCout} + \sum_{v \in V} \sum_{t \in T} R_{vt}^{S} y_{vt}^{S} \\
& - \sum_{v \in V} \sum_{t \in T} C_{vt}^{TC} y_{vt}^{TCin} - \sum_{v \in V} \sum_{t \in T} C_{vt}^{I} y_{vt}^{I} \\
& - \sum_{v \in V} \sum_{t \in T} C_{vt}^{N} y_{vt}^{N} - \sum_{v \in V} \sum_{r \in R_v} \sum_{t \in T_v} C_{vr} x_{vrt} \\
& - \sum_{v \in V} \sum_{t \in T} \left(C_{vt}^{O} + C_{vt}^{C} \right) y_{vt}^{OWN},
\end{aligned} \quad (1)$$

The objective function (1) maximizes the profit. The first term gives the revenue of servicing COAs and spot contracts. The second term gives the revenue of time chartering out vessels and selling vessels while the third term gives the costs of chartering in vessel and buying vessels. The fourth term gives the cost of ordering new vessels and the voyage cost for the different routes and vessels. Finally, the fifth term gives the OPEX and CAPEX of the owned vessels.

5.5 CONSTRAINTS

5.5.1 FLEET CONSERVATION

Constraints (2) ensure that the total numbers of owned vessels are preserved. Constraints (3) ensure the same for the total number of each vessel type controlled and operated by the shipping company is conserved, while constraints (4) ensure that one does not charter out vessels that are not owned. Finally, constraints (5) ensure that vessels are sold/scrapped before their lifetimes expire.

$$y_{vt}^{OWN} = y_{v,t-1}^{OWN} + y_{vt}^{I} - y_{vt}^{S} + y_{vt}^{N}, \qquad \forall v \in V, t \in T_v, \tag{2}$$

$$y_{vt}^{TOT} = y_{vt}^{OWN} + y_{vt}^{TCin} - y_{vt}^{TCout}, \qquad \forall v \in V, t \in T_v, \tag{3}$$

$$y_{vt}^{TCout} \le y_{vt}^{OWN}, \qquad \forall v \in V, t \in T_v, \tag{4}$$

$$y_{v,t_v}^{OWN} = \sum_{t_v+1}^{t_v+T_v^{LT}} y_{vt}^{S}, \qquad \forall v \in V, \tag{5}$$

Constraints (6) and (7) defines the initial fleet, where F_v^0 is the number of owned vessels of each type. Constraints (8) ensure that no newbuildings can be ordered in the first period.

$$y_{v,0}^{OWN} = F_v^0, \qquad \forall v \in V^E, \tag{6}$$

$$y_{v,0}^{TOT} = y_{v,0}^{OWN} + y_{v,0}^{TCin} - y_{v,0}^{TCout}, \qquad \forall v \in V, \tag{7}$$

$$y_{v,0}^{N} = 0, \qquad \forall v \in V^E, \tag{8}$$

5.5.2 *Capacity*

Constraints (9) ensure that there is enough capacity in the fleet to fulfill the demand of the selected COA. Constraints (10) calculate the spot cargo transported.

$$\sum_{v \in V} \sum_{r \in R_v} Q_v A_{ivr} x_{vrt} \ge Q_{it} \delta_i, \qquad \forall i \in N^{COA}, t \in T, \tag{9}$$

$$z_{it} \le \sum_{v \in V} \sum_{r \in R_v} Q_v A_{ivr} x_{vrt}, \qquad \forall i \in N^{SPOT}, t \in T, \tag{10}$$

5.5.3 *Demand*

Constraints (11) provide an upper limit of cargo available for each spot trade.

$$z_{it} \le S_{it}, \qquad \forall i \in N^{SPOT}, t \in T, \tag{11}$$

5.5.4 TIME

Constraints (12) ensure that the total duration of all roundtrips made on a route by each vessel type is equal to or less than the total available time for all vessels of that type operated by the shipping company.

$$\sum_{r \in R_v} T_{vr} x_{vrt} \leq T_v^{TOT} y_{vt}^{TOT}, \qquad \forall v \in V,\ t \in T_v, \tag{12}$$

5.5.5 VARIABLE DOMAINS

It should be mentioned that constraints (15) do impose integrality requirements and thereby makes it possible only to charter in or out for a whole period. Constraints (17) do not impose integrality requirements making it possible to let a roundtrip endure over a change of periods.

$$\delta_i \in \{0,1\}, \qquad \forall i \in N^{COA}, \tag{13}$$

$$y_{vt}^{OWN}, y_{vt}^{S} \geq 0 \text{ and integer}, \qquad \forall v \in V, t \in T_{,} \tag{14}$$

$$y_{vt}^{TOT}, y_{vt}^{TCout}, y_{vt}^{TCin} \geq 0 \text{ and integer}, \qquad \forall v \in V,\ t \in T_v, \tag{15}$$

$$y_{vt_v}^{I}, y_{vt_v}^{N} \geq 0 \quad \text{and integer}, \qquad \forall v \in V, \tag{16}$$

$$x_{vrt} \geq 0, \qquad \forall v \in V,\ r \in R_v,\ t \in T_v, \tag{17}$$

$$z_{it} \geq 0, \qquad \forall i \in N^{SPOT}, t \in T, \tag{18}$$

6 CASES

This chapter aims to show some of the areas of application for the optimization model. A fictional setting is presented where a management of a newly formed shipowning company wants to investigate the profitability for different strategies. Even though the setting is fictional, it is not unrealistic. A short description regarding the input data and collection of these are also given.

6.1 SETTING

The two ship owning companies *Alfa Bulk* and *Bulk Bravo* are engaged in worldwide trade of coal and grain. In order to gain a larger market share and become more competitive they will merge into one large operator, *World Bulk Carriers (WBC)*. The combined fleet will consist of 5 Supramax, 10 Panamax and 5 Capesize vessels. The new board of WBC is working on determining a new strategy for the company. The merge has gained attention in the dry bulk market and WBC has several new long term COAs under consideration. The board is interested in finding out if the existing merged fleet is sufficient for the new company or if they should consider replacing vessel types and/or acquiring additional vessels. Another option under evaluation is to terminate all cargo transportation activity and only focus on trading vessels and time charter out vessels.

There are 4 long-term COAs under consideration and additional 3 spot contracts with an upper limit available for transportation for each period. The value of the long-term COAs is based on the whole contract i.e. demand for all periods must be fulfilled in order to be able to commit to the contract. For the spot contracts there is an upper limit allowing the company to decide whether they want to take on any spot cargo at all. If they decide to do so, they cannot transport more than the upper limit for each period.

Detailed information about each of the contracts, both COAs and spot contracts, can be found in Table 5 and Table 6. The COAs has a total value while the spot contracts give the revenue per ton transported. The amount to be transported is given in ton and is specified for each period for the COAs while for the spot contracts it is the upper limit that is presented.

Contract nr	Type	Commodity	Loading port	Unloading port	$/ton
1	COA	Thermal Coal	Australia, Newcastle	Japan, Wakayama	14
2	COA	Thermal Coal	Australia, Newcastle	China, Qinhuangdao	10
3	COA	Thermal Coal	East Coast US, Baltimore	Europe, Rotterdam	17
4	COA	Coking Coal	East Coast US, Baltimore	Japan, Wakayama	20
5	Spot	Grain	East Coast US, Baltimore	Europe, Rotterdam	19
6	Spot	Grain	Australia, Newcastle	Japan, Wakayama	17
7	Spot	Grain	East Coast US, Baltimore	Japan, Wakayama	26

Table 5 - Contract data

Contract nr	Value ($)	Period 1	Period 2	Period 3	Period 4	Period 5
1	30 000 000	10 000 000	10 000 000	10 000 000	0	0
2	160 000 000	20 000 000	20 000 000	20 000 000	20 000 000	0
3	120 000 000	0	20 000 000	20 000 000	0	0
4	240 000 000	0	15 000 000	15 000 000	15 000 000	15 000 000
5		5 000 000	5 000 000	5 000 000	5 000 000	5 000 000
6		5 000 000	5 000 000	5 000 000	5 000 000	5 000 000
7		5 000 000	5 000 000	5 000 000	5 000 000	5 000 000

Table 6 - Contract data cont'd

The board has come up with three different cases that they want evaluated.

- **Case 1**
  WBC continuous to operate in the coal/grain marked without making any changes to the combined fleet. If possible, all COAs are serviced. Otherwise the COAs are chosen based on a max profit evaluation. The possibility to do this with and without using time charter (TC) should be investigated.

- **Case 2**
  WBCs fleet is optimized to handle all proposed COAs. The fleet mix and size is determined based on max profit. The options of buying second hand vessels, newbuildings and using TC are all to be considered together.

- **Case 3**
  Terminate all transporting activity and continue only with active vessel trading and TC.

The planning interval will be of 5 years from 2010 to 2014 with each period being 1 year, 5 periods in total.

6.2 Data Collection

Information about the vessels where collected from similar vessel types through (Fairplay, 2009). Where it was found necessary the data was modified or updated. Examples of this were that specific fuel consumption was updated to fit 2010 specifications if the comparison vessels were old. A modification made was to adjust cruising speed to 14.5 knots for all vessels types. The original data can be found on the enclosed CD together with the modified data. The vessel types that has been used are; Supramax (55 000 DWT), Panamax (75 000DWT) and two types of Capesize, respectively on 150 000 DWT and 170 000 DWT. A typical bulk carrier layout is shown in Figure 10.

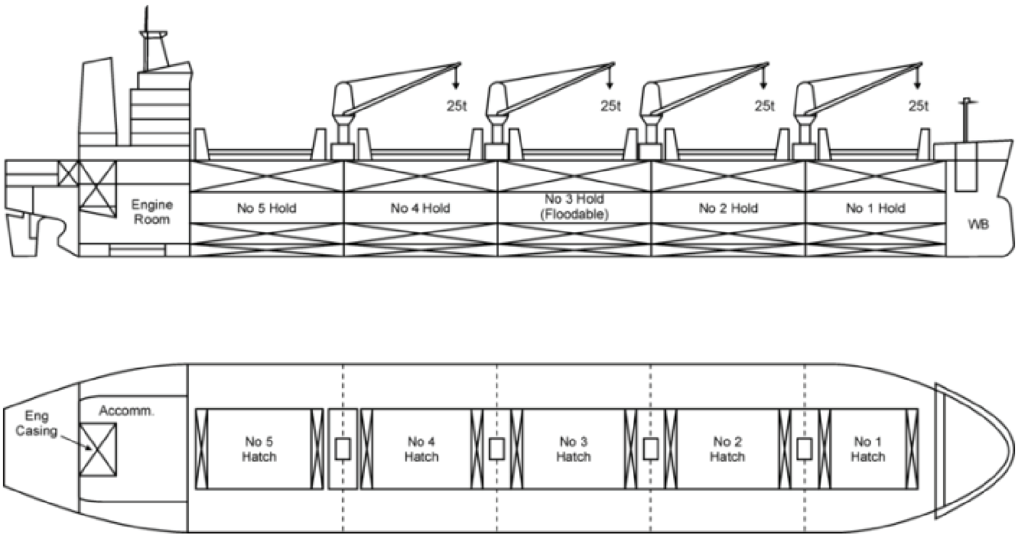

Figure 10 - General arrangement of Supramax carrier

Forecast data has been collected from (Drewry, 2009), (Drewry, 2010) and (Fearnsearch, 2010). For those parameters where data were not found or forecast data were missing for some periods, the author has made own estimates. This was done by taking the gradient from a parameter of similar type that had complete forecast data for the wanted period and use it to estimate the missing values. None of the above mentioned sources had any forecasts beyond 2014 which can indicate that forecasting beyond a time horizon of 5 years is considered highly unpredictable. All collected data can be found on the enclosed CD, color labeled according to their respective source.

7 IMPLEMENTATION

This chapter briefly describes the implementation process of the model in the optimization software. For further information regarding the process the reader is referred to the Preface.

The optimization model can be implemented in several optimization software tools. Xpress IVE was chosen since the Department of Marin Technology have license for this software. Input data was compiled in MS Excel and an attempt to make Xpress read directly from Excel was made. This proved difficult and the Excel file was then converted to a .dat file. Xpress writes the output to a .csv file ensuring easy transition back to MS Excel. Alternatively the output can be presented directly in Xpress.

FIGURE 11 - THE STRUCTURE OF OPTIMIZATION PROCESS

The layout of the output is coded in such way that it is easy to verify the results in Xpress. This part of the code may be adapted to suit any given preferences without influencing the optimization process.

There were several technical obstacles during implementation of the model in Xpress, resulting in the model not being directly transferable to the programming language MOSEL. This was solved by re-defining bounds in Xpress and adding additional constraints, ensuring that Xpress was able to execute the model.

A feature worth mentioning is the *artificial period*. Because of the definition of T_v the model forces vessels to be sold before their lifetime ends or at the end of the planning period, whichever are the lesser in number of periods. However, this becomes a problem as soon as the number of periods in the planning interval is less than the number of periods left of a vessel's lifetime. Just because a company wants to plan for e.g. 5 year at a time does not mean that it would be correct to sell a new vessel after 5 years. Therefore an artificial period is created and added to the original set of periods. In this artificial period it is only possible to sell vessels. This implies that if the model suggests selling vessels in this period it means that it could be equally beneficial to keep them in the fleet. It is worth noticing that the revenue of "selling" these vessels in the artificial period also will be added to the result. Additional remarks about the model are presented in Chapter 9.

8 RESULTS

This chapter presents the results from the various model runs in Xpress together with a brief discussion of the results. Having in mind that the cases are used only to illustrate areas of use for the optimization model, no in-depth investigations of the results have been conducted.

8.1 CASE 1 WITHOUT TC

From the summary in Table 7 we can see the result of the optimal solution. Since the model forces all vessels to be sold either before their lifetime expires or in the period after the last planning period, (which is period 6 for this and the following cases) the result also includes the value of the "remaining" vessels in the fleet in period 6.

SUMMARY CASE 1 WITHOUT TC							
Result:	**$ 1 794 902 214**						
Contracts served	**COA1**	**COA2**	**COA3**	**COA4**	**SPOT1**	**SPOT2**	**SPOT3**
Period 1	0	0	0	1	5 000 000	5 000 000	5 000 000
Period 2	0	0	0	1	176 477	0	5 000 000
Period 3	0	0	0	1	176 477	0	5 000 000
Period 4	0	0	0	1	176 477	0	5 000 000
Period 5	0	0	0	1	176 477	0	5 000 000

TABLE 7 - RESULT FROM CASE 1WITHOUT TC

We also see that only COA4 is served, this being indicated by the value of 1 for all the period COA4 is valid. The number under the different spot contracts shows how much of the available spot cargo [ton] that is being transported in each period. The graph in Figure 12 shows an overview of changes made to the fleet during the planning period.

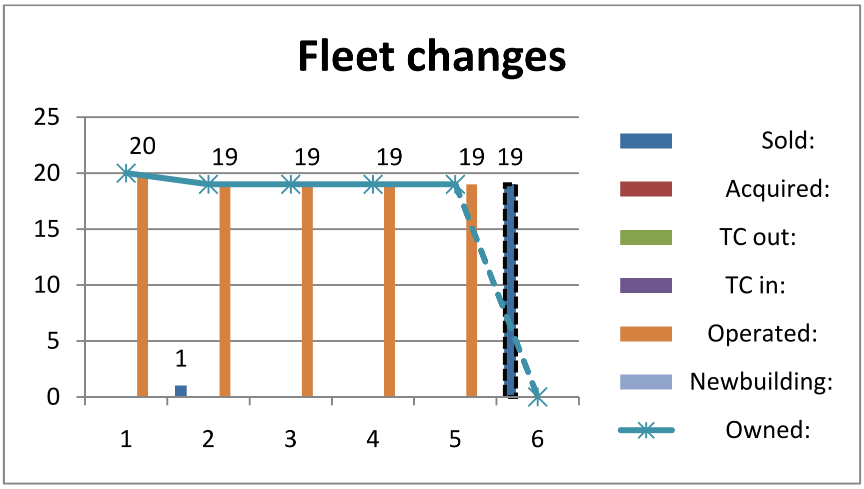

Figure 12 - Fleet changes in Case 1

It can be observed that the all the 20 vessels from the initial fleet are operated in the first period and all available spot cargo for the three spot contracts are serviced in period 1. The model then finds it most profitable to sell one Panamax in period 2 (Table 12), take on COA4 and use the remaining fleet capacity to service available spot cargo.

8.2 Case 1 with TC

When we let the model choose whether to time charter in/out vessels for each period we see that we get a higher result (ca. 94%) for the same planning period. If we look closer at the changes in the fleet we see that all 20 vessels in the initial fleet are kept in the fleet (until period 6). Table 8 shows that all COAs are serviced and almost all available spot cargo and in Table 13 we see that the model chooses to time charter out all the Supramax and Panamax vessels for all the periods. This seems rational since larger vessels are more fuel economic in operation than smaller vessels (Laake, 2009).

SUMMARY CASE 1 WITH TC							
Result:	**$ 3 053 637 060**						
Contracts served	**COA1**	**COA2**	**COA3**	**COA4**	**SPOT1**	**SPOT2**	**SPOT3**
Period 1	1	1	1	1	4 778 571	5 000 000	5 000 000
Period 2	1	1	1	1	5 000 000	5 000 000	5 000 000
Period 3	1	1	1	1	5 000 000	5 000 000	5 000 000
Period 4	1	1	1	1	5 000 000	4 607 143	5 000 000
Period 5	1	1	1	1	5 000 000	5 000 000	5 000 000

Table 8 - Result from Case 1 with TC

When it comes to chartering in vessels the model chooses different vessel types and numbers for each period, but there is a predominance of Capesize vessels that are time chartered in. This is also rational because we do not pay OPEX for vessels we time charter in, only those we own.

Since the fuel cost per ton cargo that is transported is lower for larger vessels this should also contribute to decrease the total expenditures. An overview over the fleet changes for Case 1 with TC as an option is illustrated in Figure 13. However, an issue that is open for discussion is if the number of vessels that are time chartered in is reasonable or not. Such activity requires solid cashflow and reserves. When running the model there was not set an upper boundary (UB) on how many vessels that could be TC in each period. This is however easy to configure independently for each desired case according to the users preferences.

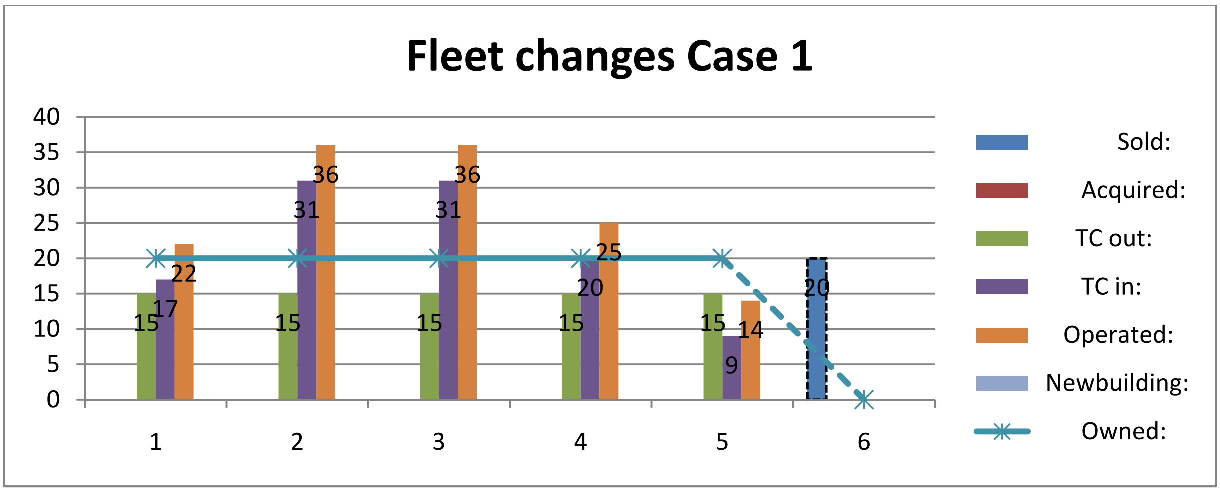

FIGURE 13 - FLEET CHANGES IN CASE 1 WITH TC

8.3 CASE 2

After trying to run the model for Case 2 with UB for $y_{vt}^{TCout} \leq 15$, $y_{vt}^{I} \leq 10$ and $y_{vt}^{N} \leq 10$ an optimal solution were not verified after 4500 seconds. Instead UBs were set to for $y_{vt}^{I} \leq 5$ and $y_{vt}^{N} \leq 5$, being more reasonable limits, but still high considered the maximum possible value of a purchase in that order of magnitude. Now the model was stopped manually after 214 seconds, having reached an optimality gap of 0.0618%. This gave the following result provided in Figure 14. As we see, the graph indicates that it is profitable to buy both newbuildings and second-hand vessels in order to time charter them out. Even if we set an UB on y_{vt}^{TCout} the model will continue to buy as much as it is allowed to buy, after the necessary fleet capacity to carry all COAs and spot contracts has been covered.

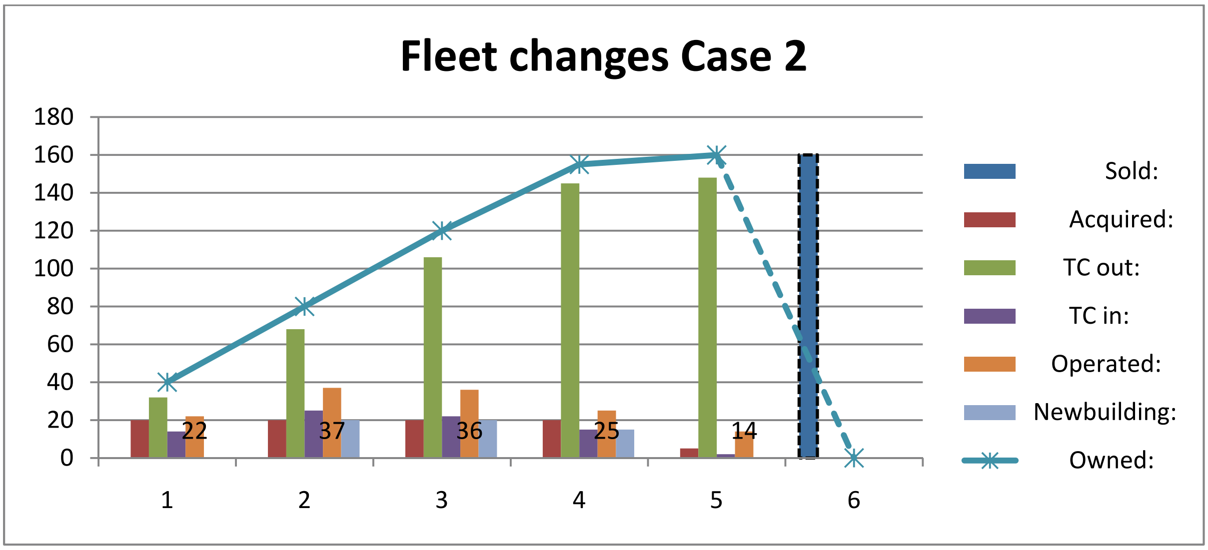

FIGURE 14 - FLEET CHANGES IN CASE 2, 1ST MODEL RUN

As it is highly unlikely for a single operator to purchase 140 vessels over a 5 year period it may indicate that the input data used is not the most appropriate to model a real world scenario or that there should be an upper limit for how much capital that is available for each period. Otherwise it is worth noticing that the numbers of operated vessels in each period are almost identically the same as for Case 1 with TC.

In order to present a more realistic result we set UB for the different variables to $y_{vt}^{TCout} \leq 1$, $y_{vt}^{I} \leq 2$, $y_{vt}^{TCin} \leq 3$ and $y_{vt}^{N} \leq 2$. This gave an optimal solution after 0.9 seconds with an optimality gap of 0.00985% and the following result presented in Table 9 and Figure 15 below.

SUMMARY CASE 2							
Result:		**$ 3 199 742 985**					
Contracts served	**COA1**	**COA2**	**COA3**	**COA4**	**SPOT1**	**SPOT2**	**SPOT3**
Period 1	1	0	1	1	4 553 043	5 000 000	5 000 000
Period 2	1	0	1	1	5 000 000	5 000 000	5 000 000
Period 3	1	0	1	1	5 000 000	5 000 000	5 000 000
Period 4	1	0	1	1	5 000 000	5 000 000	5 000 000
Period 5	1	0	1	1	5 000 000	4 748 527	5 000 000

TABLE 9 - RESULT FROM CASE 2, 2ND MODEL RUN

The result from the 2nd model run for Case 2 proves to have the highest result and yet all COAs are not served. This can imply that the model finds it more profitable to trade vessels, both within the TC market and the second-hand market, than to cover all COAs. This is further substantiated by the sale of 11 vessels in period 4 and the acquisition of 6 vessels while also ordering 3 newbuildings in the same period, as we see in Figure 15. A more detailed overview of the fleet changes is presented in Table 14 in Appendix A.

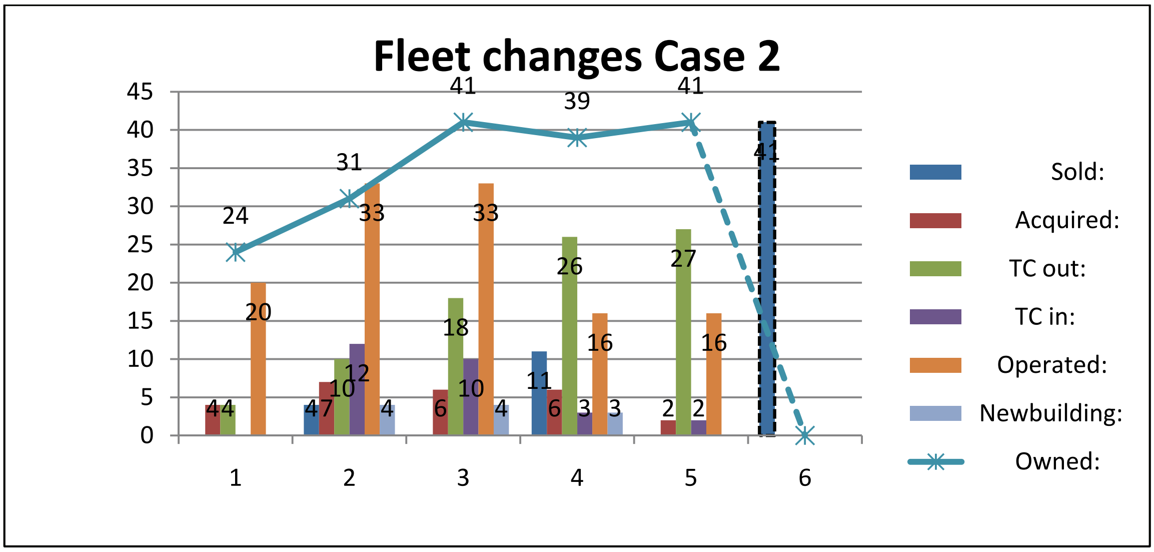

Figure 15 - Fleet changes in Case 2, 2nd model run

8.4 Case 3

The objective of this case was to investigate how profitable it would be to only be engaged in trading vessels, not taking on any contracts. The options for the use of the initial fleet would then be to TC out or to sell the vessels. The result turns out to be lowest of the three, which alludes to it being more profitable concentrating on transporting cargo or to combine both.

SUMMARY CASE 3							
Result:	$ 1 725 004 280						
Contracts served	**COA1**	**COA2**	**COA3**	**COA4**	**SPOT1**	**SPOT2**	**SPOT3**
Period 1	0	0	0	0	0	0	0
Period 2	0	0	0	0	0	0	0
Period 3	0	0	0	0	0	0	0
Period 4	0	0	0	0	0	0	0
Period 5	0	0	0	0	0	0	0

Table 10 - Result from Case 3

Case 3 was run with no UB for y_{vt}^{TCout} and y_{vt}^{TCin} due to the objective of the case, while UB was held at $y_{vt}^{I} \leq 2$ and $y_{vt}^{N} \leq 2$ for buying second-hand vessels and ordering newbuildings. As expected the resulting fleet changes corresponds to what we found in Case 2, that is the model buying as much as allowed in order to TC out the vessels. Fleet changes are presented in Figure 16.

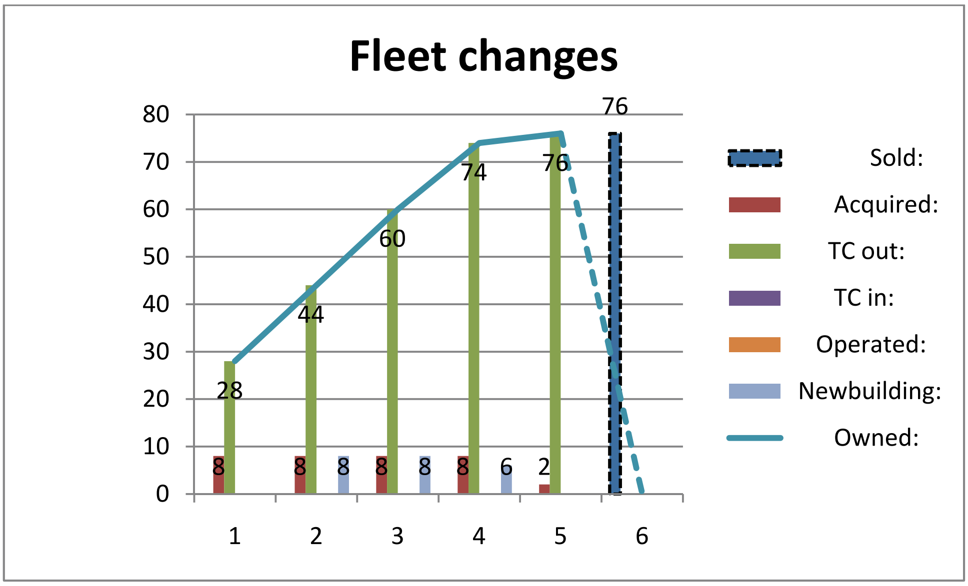

FIGURE 16 - FLEET CHANGES IN CASE 3

A more detailed overview of the fleet changes is presented in Table 15 in Appendix A.

8.5 SENSITIVITY TO INPUT DATA

The optimal solution is directly related to the input data and this data may or may not always be of absolute certainty. Such uncertainties are often present when using forecast data. Since the model is to be used as a support for taking important strategic decisions it is essential to know if the model is sensitive to variations in the input data. In order to do this, three forecast scenarios is used. These are *Recovery* (15% market increase per period), *Trough* (0% increase per period) and *Collapse* (15% decrease per period). With market increase/decrease we here mean developments in parameters such as freight rates, vessel prices, fuel price etc. By assuming that the collected forecast data is correct, these three scenarios are only applied to parameter values which the author has estimated. Assuming that all parameters develop with the same ratio is of course a generalization of the relationship between the different market drivers. A more in-depth description of such relationships, i.a. between fuel prices and freight rates, can be found in (UNCTAD, 2010).

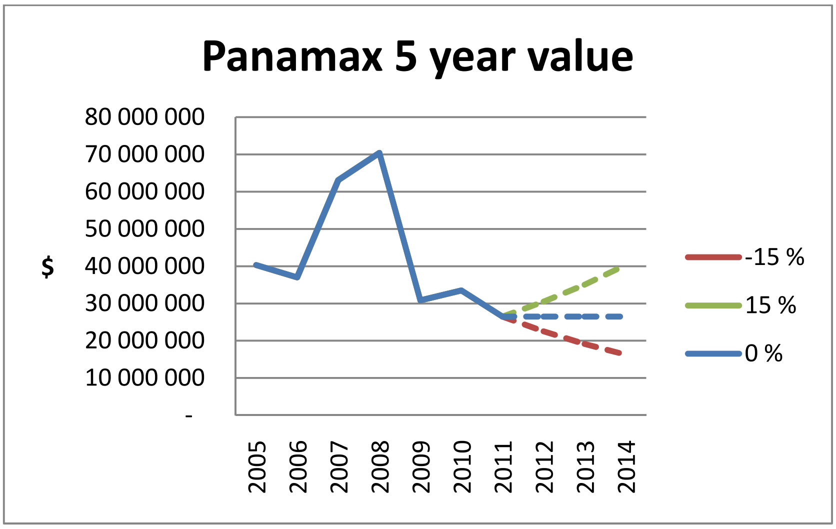

FIGURE 17- FORECAST FOR A PANAMAX 5 YEAR VALUE

The graph in Figure 17 shows the development of prices for 5 year old Panamax vessels with possible future realizations for each of the three scenarios. The scenarios are rather moderate when considering the volatile behavior of this parameter. However, as we remember from the description of shipping cycles and the illustration of this in Figure 1, such fluctuations are common in the maritime world.

We wanted to investigate how sensitive the model was to changes in the input data. This was done by running the model for Case 2 with input data according to the three scenarios. This turned out to give quite different results, as shown in Table 11.

Market scenario:	Trough (0 %)	Collapse (-15 %)	Recovery (15 %)
Result:	$ 3 199 742 985	$ 2 400 534 144	$ 2 791 692 369

TABLE 11 - RESULTS FROM ALL 3 SCENARIOS FOR CASE 2

It may seem peculiar that it is the *Trough* scenario with 0% changes that yield the highest result and not the *Recovery* where the freight rates are highest. However, it is not only the rates that increase with 15%, it is also the OPEX, the vessel prices and the fuel price. Similar is it for the *Collapse* scenario when the market drops. It may be tempting to ask why the results are not the same for all three scenarios if all the parameters changes with the same ratio. The reality is that they do not. In fact, as shown in Figure 18 for the *Trough* scenario the different parameters for a Panamax vessels does not have similar gradient. The same can be observed for the other scenarios in Figure 24 and Figure 25 in Appendix B. The unbroken lines represent published forecast data compiled from (Drewry, 2009), (Drewry, 2010) and (Fearnsearch, 2010) while the dotted parts are estimates conducted by the author where published data was not available.

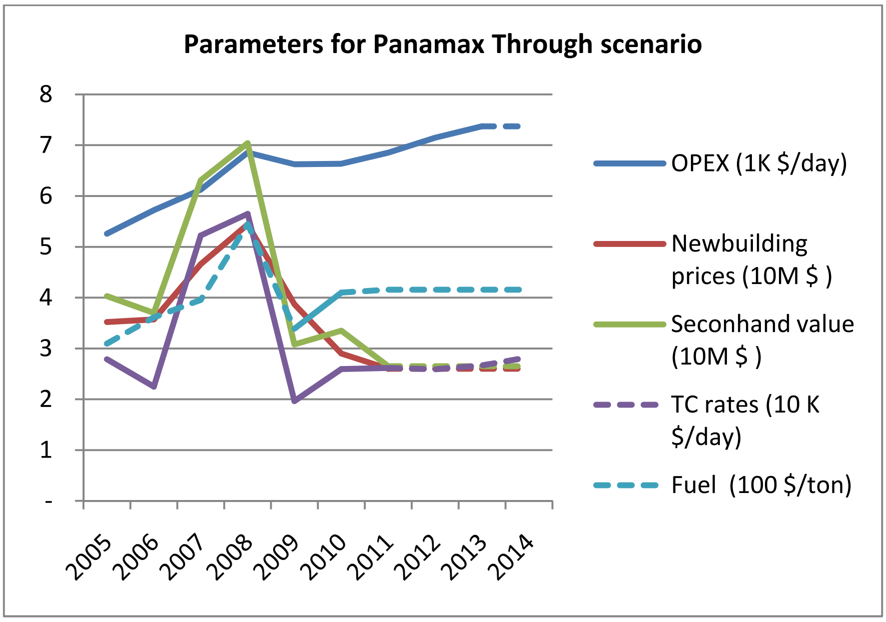

FIGURE 18 - RELATIONS BETWEEN PARAMETER DEVELOPMENTS FOR THE TROUGH SCENARIO

Having observed that the economical result is sensitive to changes in the input data it would be interesting to investigate how it effects the strategic decisions suggested by the model. If it is the similar decisions that have to be made in order to obtain optimal result for each scenario, then it can be argued that the model gives a rather robust solution. *When to order*, *buy* or *sell* vessels and *how many* are important decisions that will have large effects on the result. Also deciding which long term COAs to engage in has a significant impact. Decisions regarding spot cargo and time charter are also of importance, but the shorter time horizon for these decisions makes it easier to manage decision changes in real life.

From the graph in Figure 19 we see that the numbers of vessels that are owned and operated in each period are quite similar for the *Trough* and *Recovery* scenario. This indicates that even if you plan for the *Trough* scenario and instead the *Recovery* scenario should occur, the decisions taken could still be close to the optimal solution. However, if the *Collapse* scenario should occur we see that it requires very different choices to have been made in order to achieve the optimal result. This indicates that the optimization model does not provide a robust solution that is equally valid for different scenarios. A more detailed presentation of the different fleet changes are presented in the Appendix A

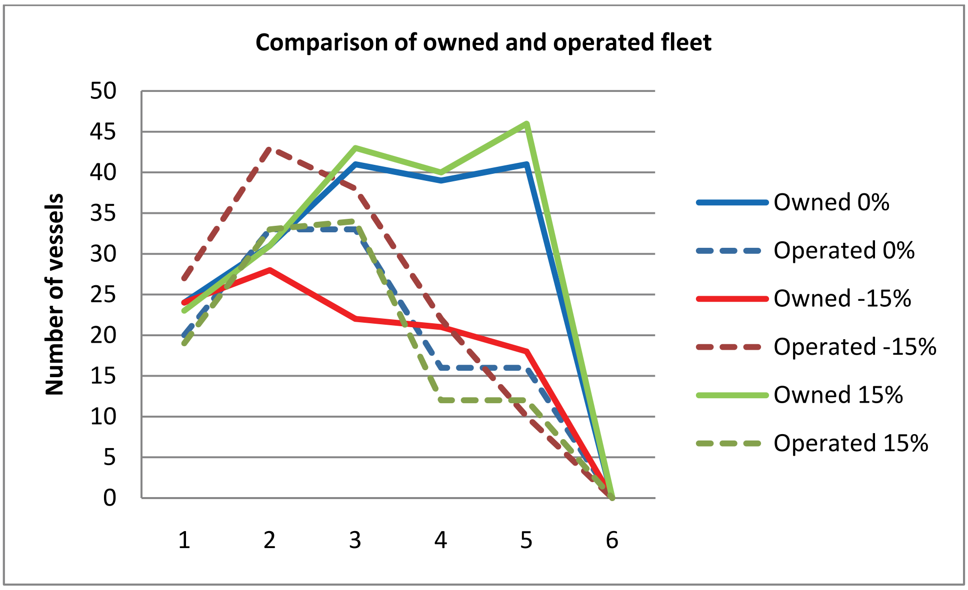

FIGURE 19 - COMPARISON OF OPERATED AND OWNED VESSELS IN CASE 2 FOR THE DIFFERENT SCENARIOS

8.6 COMMENTS

The model suggests that WBC go for the strategy proposed in Case 2. Even though this turned out to be the best strategy for this setting it is not given that it would be best in other settings. However, it is peculiar that values in the results are of a relative high order. A high degree of uncertainty can be connected to the input data, but it still seems unrealistic to obtain results that show a profit above $1 billion for a 5 year period. Due to time limitations no in-depth investigations have been conducted in order to uncover the underlying reasons for this. Without further investigations it can only be speculated in why the results turns out to be so profitable. Meanwhile it must be remembered that it not entirely correct to think of the result as the "profit". There are too many item costs such as management costs, brokerage fees, and port dues that is not included in the calculations. The fact that the value of 20 ships from the initial fleet also is included has a significant impact on the result.

9 REMARKS TO THE MODEL

Having a highly versatile area of application, the model aims to provide strategic decision support for a wide range of maritime operators. When that is said, there should also be stressed that there are aspects of the model that could be improved. This chapter aims to briefly discuss some of the shortcomings and simplifications in the model and suggest improvements that would further strengthen the model as a strategic decision support tool.

9.1 SETTING LOWER AND UPPER BOUNDARIES

It is easily to set a general lower boundary (LB) or upper boundary (UB) for e.g. how many vessels of type v that you can buy in period t or how many vessels you can time charter of vessel type v in period t. What should be improved is the possibilities to set an LB and UB on the sum of all vessels for a period, e.g. you want to be able to say that the model cannot buy more than 4 vessels in one period, whereas now it is only possible to say that you cannot buy more than 4 vessels of type v without adding extra code.

The possibility to set an UB to the available capital in each period should also be implemented. This would together with the above mentioned measures probably limit sky-high results such as we saw the tendency for in some of the model runs.

9.2 ROUTES AND CARGO

Being a strategic decision support tool the model has some weaknesses when it comes to tactical issues. The model uses predefined routes and it does not take into account the time and cost when a vessel is transferred from a route to another. This is however considered to have a minor influence on the result as a voyage between two routes has little impact in the long run of a strategic plan. The user should anyhow bear in mind that this will result in an overoptimistic solution. Another assumption that has been made is that each vessel take full loads and does not mix cargoes from different contracts. The model does neither arrange backhaul cargoes, unless this is predefined in the routes, resulting in a maximum of 50% ballast journeys.

9.3 SALES PRICE AND CAPEX

When considering the future price a vessel will be sold for, there are two main options. One is to base the price on market forecast data. Such forecasts are derived by looking at the different influencing factors such as the order books of the world's yards to determine how many new vessels will reach the market. The age of the world's vessels in that segment must also be taken into consideration to determine how many vessels that will be scrapped. From this it will then be possible to conduct an estimate of the future availability of tonnage. In according to this an estimate must also be made for the future demand of tonnage, as the price is a function of supply and demand. Considering the many different factors that can influence the world economy and demand of tonnage, the result may be highly inaccurate. It may also prove to become increasingly more inaccurate proportional to the length of the forecast period, as illustrated by the example in Figure 20.

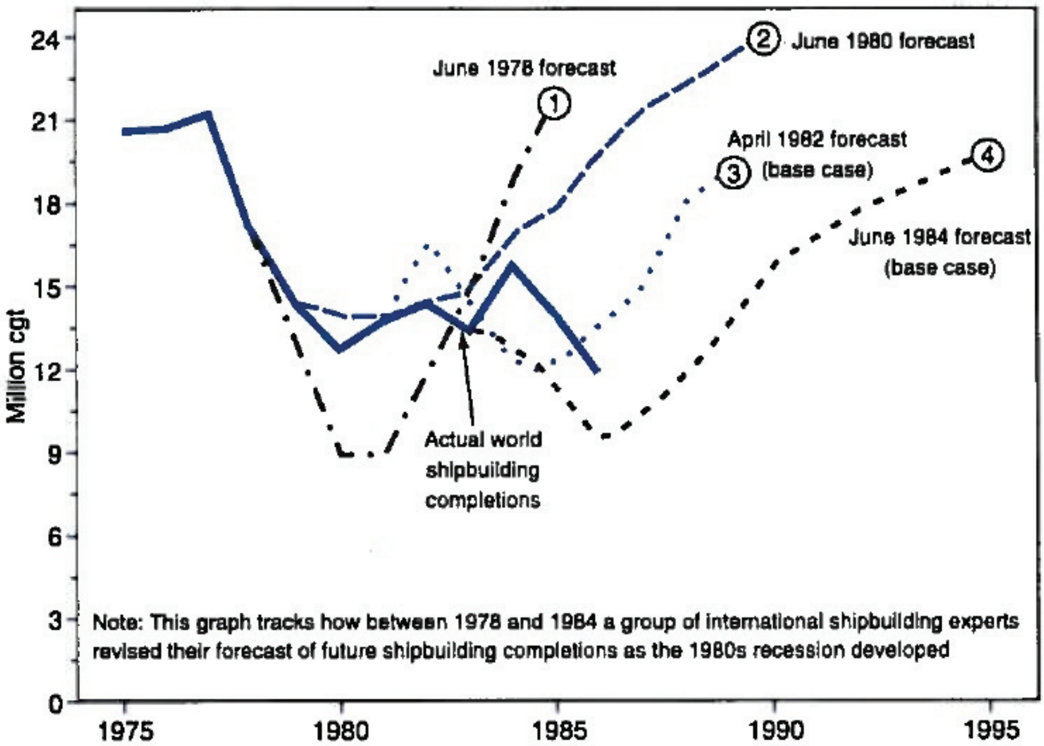

FIGURE 20 - COMPARISON OF FORECASTS OF WORLD SHIPBUILDING COMPLETIONS

Source: Martin Stopford, 2009

The other method, which is implemented in the model, calculates the sales price by subtracting the ship's annual depreciation from its acquisition value. The method used is the *straight-line depreciation* which implies that the value of the ship is written off in equal proportions over its expected lifetime. This simplification does not cover the market aspects and excludes by that an important market mechanism. It is debatable whether this contributes to increase or decrease the probability for a solution that will be in accordance with real life. In the end it is up to the users of the model to decide to use the input data on which they rely on the most.

The CAPEX is calculated based on an assumption that all vessels are acquired with a loan corresponding to 80% of the acquisition price and with an interest rate of 10% per anno on that loan. These parameters can easily be changed for each scenario. It is debatable whether these values are realistic or not.

9.4 Newbuilding and Second Hand Acquisitions

An important note to make is that newbuildings are not defined as part of the owned fleet in the first period. This is to take into account that the vessels must be built before they can be used. As it is now, the Xpress code does not show the user when to order a newbuilding in order to have it delivered at the period the model suggest it should be used. For the end-user this implies that a newbuilding order must be placed so that it is ready for delivery in the period the model suggests. This also gives an unnatural effect to the economic result as the cost of the newbuilding is calculated for the delivery period. This could be re-modeled so that newbuildings would be delivered in a later period than the ordering period. The building time should then be a dynamic set of periods, as it will change in accordance with the supply and demand among yards and shipowners.

Another simplification that has been made is that the whole amount is paid upon receiving a newbuilding while in fact it is normal to divide the amount into five stages; 10% when signing the contract and 22,5% at the beginning of steel cutting, keel laying, launching and the final 22,5% at delivery (Stopford, 2009).

9.5 Vessel Lifetime and the Sales Constraints

Normal lifetime for a merchant vessel is considered to be 20-25 years. The sales constraints (5) will force the model to sell a vessel before it reaches its maximum lifetime. However, a problem occurs if the model is run for a planning scenario shorter than this since the vessel period T_v is an array of vessel type V and periods T in the planning interval. This can be further illustrated by an example:

Consider a planning period of 10 years. In this case the maximum T_v^{LT} cannot be higher than 10 years because of the definition of T_v. For a new vessel bought in period 1 it would, in many cases, be unrealistic to sell it just because the planning interval is shorter than the vessel's lifetime. This aspect is taken care of by creating an artificial period $T_{\max}+1$ in which the vessel also can be sold. The period $T_{\max}+1$ also corresponds to $t_v + T_v^{LT}$. The sales price in period $T_{\max}+1$ represents the remaining value of the vessel so if the model result suggests selling a vessel in period $T_{\max}+1$ it means in fact that it could be equally beneficial to sell the vessel as to keep the vessel in the fleet. Whether this should be done or not could be clarified by rerunning the model, say once a year, when new forecast data is available or by extending the duration of the planning period.

9.6 Time Chartering

The model offers the possibility to evaluate whether it could be profitable to time charter in/out vessels. The rates/cost for time chartering in vessels are set to 5% higher than the rates/revenue you get for time chartering out vessels. This is only done in the input file and is not a feature of the model. The reason for why this has been done is to prevent the model from charter in a vessel for only to charter it out again for the same price. Such actions do not contribute to either transporting cargo or increasing the profit, only to increase the number of calculations. It is debatable whether 5% difference is realistic or not.

The model should also be extended to take account for vessels already on TC when the planning begins. As of now, it is only possible to determine an initial fleet for the first period. This could be changed to we can define how many of vessel type v that is already on TC when the planning starts. A suggestion to this is the following code:

$$y_{v,0}^{TCin} = TC_v^{in}, \qquad \forall v \in V^E,$$

$$y_{v,0}^{TCout} = TC_v^{out}, \qquad \forall v \in V^E,$$

Where TC_v^{in} and TC_v^{out} is the number of vessels time chartered in and out in period 0.

Another simplification made in the model is that time charter is only possible for one period at a time. In real life, time charter can be anything from days to years. This will also be reflected in the difference in rates which will vary with the duration of the TC, according to how shipowner and charterer think the market will develop.

9.7 FREQUENCY CONSTRAINTS

Some contracts may have a requirement of a certain frequency of service during a period. If so, a constraint could be added to ensure that the frequency of services for contract i is maintained. This would be ensured by the following constraints:

$$\sum_{v \in V} \sum_{r \in R_v} A_{ivr} x_{vrt} \geq N_{it} \delta_i, \qquad \forall i \in N^{COA},\ t \in T,$$

Where N_{it} is the minimum number of roundtrips servicing contract i in period t.

10 CONCLUSION

“Prediction is very difficult, especially if it's about the future."

Nils Bohr, Nobel laureate in Physics

As all markets, the shipping market has two components, demand and supply. The freight rate is the mechanism that keeps the relationship between these two in balance by influencing the decisions and activity of shipowners and shippers.

The demand is linked to the world economy and there is a close relationship between the amount of industrial goods produced and the demand for tonnage. By monitoring trends in the world economy one will have an indicator for how the shipping market will develop. Other factors of influence are political events, conflicts, wars, and changes in commodity patterns. These can often be more difficult to predict, especially for a shipowning organization alone. Just imagine trying to predict the headings of tomorrow’s newspaper. The task is near to impossible because the world is too complex.

The supply is regulated by the number of newbuildings, scrapping and freight rates. Also the geographical location of vessels will have a short-time impact on the supply. On top of this we have the market sentiment with its unpredictable psychological factors. Shipowners do sometimes make decision based on the gut feeling or intuition, making it hard to use economical logic to predict their behavior. It is not an understatement to say that the shipping market is of an unpredictable nature. So how do we proceed to predict the unpredictable?

The optimization model presented in this master thesis is a deterministic model. This means that one assumes that all data elements are known, involving presumptions regarding realizations of future data elements such as freight rates and vessel prices. Based on this assumption the optimal solution is found. The problem lies in the uncertainty of conducting these predictions. Since the validity of the result relies in great extent of the validity of the input data, the prediction must turn out to coincide with the real life development in order for the result to maintain its validity. As we discussed earlier, there is a high probability for these predictions turning out be inaccurate or wrong. Forecasters are called upon when we need to predict the unpredictable, and by the nature of this problem they must also be expected to be wrong. This is what we know as the *forecasting paradox*. Forecast data and models for predicting the future has a poor track record and more often than not to does predictions turn out to be wrong. Humorously it can be said that there is two types of forecast; lucky or wrong! The question then arises if an optimization model like the one presented in this master thesis has any value at all for strategic decision makers?

The answer is yes. It is important to take forecast data as what it is, a qualified guess. It is not meant to give a correct answer on how the future will be but to help decision makers reduce the uncertainty connected to strategic decisions. By using information about the present to better understand the future we can clarify risks and reveal possible opportunities. That is also the purpose of the optimization model presented.

However, in chapter 8.5 we saw how a relative small change in the development of the parameters resulted in very different decision suggestions. Unless a planner is able to see into the future and know how the market will develop, one cannot but hope that the scenario you have planned for will take place. If another scenario should develop, e.g. spot rates will decrease instead of the planned increase, the result can in worst case be disastrous for a shipowner. He can end up with newly bought vessels being laid up. If he in addition has used extensive loans in lack of equity capital to cover the acquisitions of the new vessels, bankruptcy may be imminent. The further ahead the planning period stretches into the future, the higher is the probability for the forecast data being inaccurate or wrong. This should be kept fresh in mind when evaluating the results of a deterministic optimization model.

The quote of Nils Bohr grasps the essence of what all managements face when conducting strategic planning. It is problematic to model problems when we know that some of the data elements are hard to predict. Similar is it difficult to make strategic decisions for an unknown future. Shipping involves making large investments and shipowner turns to forecasts and prediction models because there is better to have an uncertain decision basis than none at all. As long as the uncertainty can be reduced it will have a value for the user.

The deterministic model proved to give valuable information about different scenarios, but it is dependent on that the scenario used actually turns out in real life. It has its weakness in only being able to evaluate the scenarios individually. If it were able to compare and evaluate scenarios collectively, it would be of higher value since this would provide a more robust solution. Stochastic modeling offers this opportunity. Unfortunately, no time was available to transform the deterministic model into a stochastic model. Such a model would be of greater value for strategic decision makers, contributing to further mitigating the uncertainties connected with strategic decision making. Stochastic optimization will be briefly introduced and put in a relevant context in Chapter 11.

11 FURTHER WORK

The original scope of this thesis was to compare the results of a deterministic and a stochastic model. This turned out to be to extensive to cover, especially because the implementation of the model in the optimizer software Xpress IVE turned out to be quite more time consuming than expected. This chapter aims to elaborate around the possibilities of expanding the presented deterministic model to a stochastic model.

The deterministic model may not be the optimal tool for strategic decision support, but it will give an indication of which decisions to make in order to play the market successfully. It is also a good foundation for developing a stochastic model. While deterministic modeling can be used to evaluate different scenarios individually, stochastic modeling is able to evaluate several scenarios collectively. This means that one get a solution that balances the impact of the different scenarios and thereby also provides a more robust solution. (Higle, 2005) gives a good introduction to stochastic programming and is recommended for readers which are inexperienced within this area.

The problem with linear programming, such as deterministic optimization, is that it assumes that all data elements are known. As we have seen this is not the case. When dealing with forecast data most of the elements are subject to some degree of uncertainty. When developing a stochastic model it is important to categorize the decisions according to when they have to be made, relative to the planning period. This is because decisions that can be put on hold to until new information about uncertain data has been received offers a possibility to adapt or adjust the current solution. This adaption is referred to as *recourse.*

Recourse involves adapting a solution to a specific observed outcome and *recourse* problems have always two or more decision stages. The *recourse* problem can also be dived into three main elements, the scenario tree, scenario problems and the nonanticipativity constraints. *A scenario is one specific, complete realization of the stochastic elements that might appear during the course of the problem* (Higle, 2005). This could be e.g., different developments of the freight rate over the duration of the planning period. *The scenario tree is a structured distributional representation of the stochastic elements and the manner in which they may evolve over the period of time represented in the problem (Higle, 2005)*. If we look back to the scenarios in chapter 8.5 and continue to look at the freight rates, the scenario tree could be similar to the one in Figure 21.

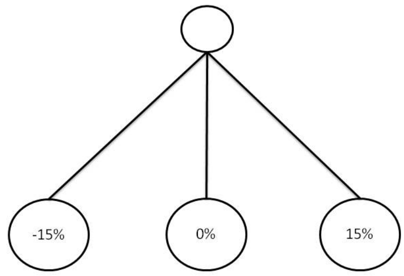

FIGURE 21 - SCENARIO TREE

The root node corresponds to the initial decision stage. At this point, information regarding the random variables is not yet available. The leaf nodes correspond to the finale decision stage when the missing information has been obtained. For the cases presented in Chapter 6 we could say e.g., the COAs and their values are known while the spot cargo available would be hard to estimate for more than one year at a time. With this as basis the decision of how many vessels to TC in/out could be delayed until one has obtained more certain data. y_{vt}^{TCin}, y_{vt}^{TCout} and y_{vt}^{I} would be the recourse variables while the number of newbuildings, which has a delivery time could be a first stage decision variable. This is only one of many ways to structure a stochastic model that could mitigate the risk for making the wrong decision.

This is without doubt a very interesting area within maritime strategic planning and further work should be carried out in order to find out if the stochastic optimization is supreme to deterministic optimization models for the type of planning problems that have been covered in this master thesis and also problems of similar type and relevance for shipowners.

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APPENDIX A

RESULTS FROM THE CASES

Results from Case 1 without TC – Trough scenario (0%)

	Sold	Acquired	TC out	TC in	Owned	Operated	Newbuildings
Period 1							
Supramax	0	0	0	0	5	5	0
Panamax	0	0	0	0	10	10	0
Capesize1	0	0	0	0	5	5	0
Capesize2	0	0	0	0	0	0	0
Period 2							
Supramax	1	0	0	0	4	4	0
Panamax	0	0	0	0	10	10	0
Capesize1	0	0	0	0	5	5	0
Capesize2	0	0	0	0	0	0	0
Period 3							
Supramax	0	0	0	0	4	4	0
Panamax	0	0	0	0	10	10	0
Capesize1	0	0	0	0	5	5	0
Capesize2	0	0	0	0	0	0	0
Period 4							
Supramax	0	0	0	0	4	4	0
Panamax	0	0	0	0	10	10	0
Capesize1	0	0	0	0	5	5	0
Capesize2	0	0	0	0	0	0	0
Period 5							
Supramax	0	0	0	0	4	4	0
Panamax	0	0	0	0	10	10	0
Capesize1	0	0	0	0	5	5	0
Capesize2	0	0	0	0	0	0	0
Period 6							
Supramax	4	0	0	0	0	0	0
Panamax	10	0	0	0	0	0	0
Capesize1	5	0	0	0	0	0	0
Capesize2	0	0	0	0	0	0	0

Table 12 - Detailed fleet changes: Case 1 without TC, Trough scenario

Results from Case 1with TC – Trough scenario (0%)

	Sold	Acquired	TC out	TC in	Owned	Operated	Newbuilding
Period 1							
Supramax	0	0	5	0	5	0	0
Panamax	0	0	10	0	10	0	0
Capesize1	0	0	0	3	5	8	0
Capesize2	0	0	0	14	0	14	0
Period 2							
Supramax	0	0	5	1	5	1	0
Panamax	0	0	10	0	10	0	0
Capesize1	0	0	0	9	5	14	0
Capesize2	0	0	0	21	0	21	0
Period 3							
Supramax	0	0	5	1	5	1	0
Panamax	0	0	10	0	10	0	0
Capesize1	0	0	0	9	5	14	0
Capesize2	0	0	0	21	0	21	0
Period 4							
Supramax	0	0	5	0	5	0	0
Panamax	0	0	10	0	10	0	0
Capesize1	0	0	0	0	5	5	0
Capesize2	0	0	0	20	0	20	0
Period 5							
Supramax	0	0	5	0	5	0	0
Panamax	0	0	10	0	10	0	0
Capesize1	0	0	0	0	5	5	0
Capesize2	0	0	0	9	0	9	0
Period 6							
Supramax	5	0	0	0	0	0	0
Panamax	10	0	0	0	0	0	0
Capesize1	5	0	0	0	0	0	0
Capesize2	0	0	0	0	0	0	0

Table 13 - Detailed fleet changes: Case 1 with TC, Trough scenario

RESULTS FROM CASE 2 – TROUGH SCENARIO (0%)

	Sold	Acquired	TC out	TC in	Owned	Operated	Newbuilding
Period 1							
Supramax	0	0	1	0	5	4	0
Panamax	0	1	1	0	11	10	0
Capesize1	0	2	1	0	7	6	0
Capesize2	0	1	1	0	1	0	0
Period 2							
Supramax	4	1	3	0	3	0	1
Panamax	0	2	2	0	14	12	1
Capesize1	0	2	2	6	10	14	1
Capesize2	0	2	3	6	4	7	1
Period 3							
Supramax	0	1	5	0	5	0	1
Panamax	0	1	5	0	16	11	1
Capesize1	0	2	4	6	13	15	1
Capesize2	0	2	4	4	7	7	1
Period 4							
Supramax	0	1	6	0	6	0	0
Panamax	10	1	7	0	8	1	1
Capesize1	0	2	7	0	16	9	1
Capesize2	1	2	6	3	9	6	1
Period 5							
Supramax	0	0	6	0	6	0	0
Panamax	0	0	7	0	8	1	0
Capesize1	0	2	8	0	18	10	0
Capesize2	0	0	6	2	9	5	0
Period 6							
Supramax	6	0	0	0	0	0	0
Panamax	8	0	0	0	0	0	0
Capesize1	18	0	0	0	0	0	0
Capesize2	9	0	0	0	0	0	0

TABLE 14 - DETAILED FLEET CHANGES: CASE 2, TROUGH SCENARIO

Results from Case 3 – Trough scenario (0%)

	Sold	Acquired	TC out	TC in	Owned	Operated	Newbuilding
Period 1							
Supramax	0	2	7	0	7	0	0
Panamax	0	2	12	0	12	0	0
Capesize1	0	2	7	0	7	0	0
Capesize2	0	2	2	0	2	0	0
Period 2							
Supramax	0	2	11	0	11	0	2
Panamax	0	2	16	0	16	0	2
Capesize1	0	2	11	0	11	0	2
Capesize2	0	2	6	0	6	0	2
Period 3							
Supramax	0	2	15	0	15	0	2
Panamax	0	2	20	0	20	0	2
Capesize1	0	2	15	0	15	0	2
Capesize2	0	2	10	0	10	0	2
Period 4							
Supramax	0	2	17	0	17	0	0
Panamax	0	2	24	0	24	0	2
Capesize1	0	2	19	0	19	0	2
Capesize2	0	2	14	0	14	0	2
Period 5							
Supramax	0	0	17	0	17	0	0
Panamax	0	0	24	0	24	0	0
Capesize1	0	2	21	0	21	0	0
Capesize2	0	0	14	0	14	0	0
Period 6							
Supramax	17	0	0	0	0	0	0
Panamax	24	0	0	0	0	0	0
Capesize1	21	0	0	0	0	0	0
Capesize2	14	0	0	0	0	0	0

Table 15 - Detailed fleet changes: Case 3, Trough scenario

Results from Case 2 – Collapse scenario (-15%)

	Sold	Acquired	TC out	TC in	Owned	Operated	Newbuilding
Period 1							
Supramax	0	0	1	0	5	4	0
Panamax	0	1	1	0	11	10	0
Capesize1	0	2	0	2	7	9	0
Capesize2	0	1	1	4	1	4	0
Period 2							
Supramax	4	0	1	1	1	1	0
Panamax	0	2	2	1	14	13	1
Capesize1	0	2	2	12	10	20	1
Capesize2	0	1	3	9	3	9	1
Period 3							
Supramax	1	0	0	0	0	0	0
Panamax	10	0	2	3	4	5	0
Capesize1	0	1	4	14	12	22	1
Capesize2	0	2	4	9	6	11	1
Period 4							
Supramax	0	0	0	0	0	0	0
Panamax	4	0	0	0	0	0	0
Capesize1	1	2	5	6	13	14	0
Capesize2	0	2	4	4	8	8	0
Period 5							
Supramax	0	0	0	0	0	0	0
Panamax	0	0	0	0	0	0	0
Capesize1	0	0	6	0	13	7	0
Capesize2	3	0	3	1	5	3	0
Period 6							
Supramax	0	0	0	0	0	0	0
Panamax	0	0	0	0	0	0	0
Capesize1	13	0	0	0	0	0	0
Capesize2	5	0	0	0	0	0	0

Table 16 - Detailed fleet changes: Case 2, Collapse scenario

Results from Case 2 – Recovery scenario (15%)

	Sold	Acquired	TC out	TC in	Owned	Operated	Newbuilding
Period 1							
Supramax	0	0	1	0	5	4	0
Panamax	0	0	1	0	10	9	0
Capesize1	0	2	1	0	7	6	0
Capesize2	0	1	1	0	1	0	0
Period 2							
Supramax	4	1	3	1	3	1	1
Panamax	0	2	3	0	14	11	2
Capesize1	0	2	2	6	10	14	1
Capesize2	0	2	3	6	4	7	1
Period 3							
Supramax	0	2	4	0	6	2	1
Panamax	0	1	5	0	16	11	1
Capesize1	0	2	4	6	13	15	1
Capesize2	0	2	5	3	8	6	2
Period 4							
Supramax	0	1	7	0	8	1	1
Panamax	10	1	7	0	8	1	1
Capesize1	1	2	7	0	15	8	1
Capesize2	2	2	7	0	9	2	1
Period 5							
Supramax	0	0	7	0	8	1	0
Panamax	0	1	9	0	10	1	1
Capesize1	0	1	9	0	17	8	1
Capesize2	0	1	9	0	11	2	1
Period 6							
Supramax	8	0	0	0	0	0	0
Panamax	10	0	0	0	0	0	0
Capesize1	17	0	0	0	0	0	0
Capesize2	11	0	0	0	0	0	0

Table 17 - Detailed fleet changes: Case 2, Recovery scenario

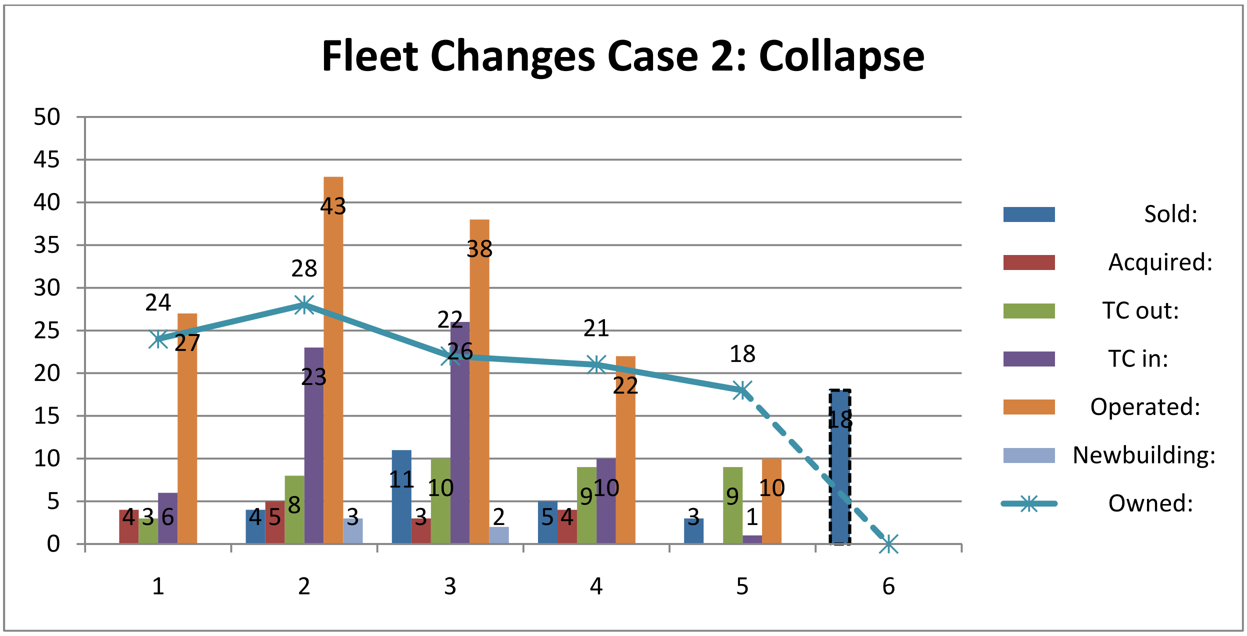

FIGURE 22 - FLEET CHANGES CASE 2: COLLAPSE SCENARIO

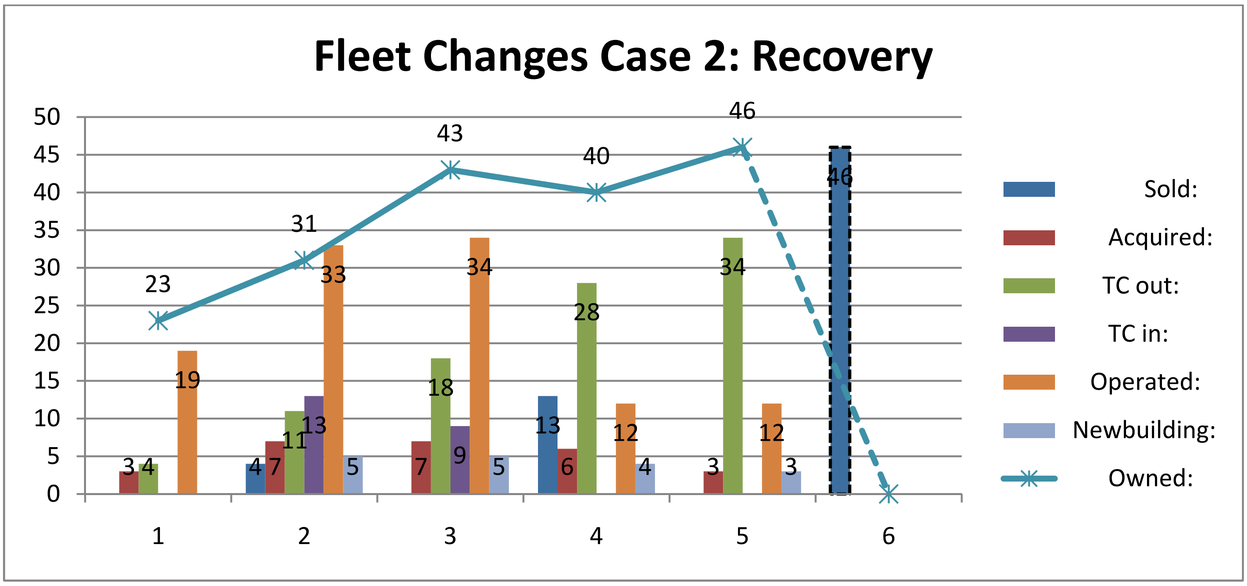

FIGURE 23 - FLEET CHANGES CASE 2: RECOVERY SCENARIO

APPENDIX B

DIFFERENCES IN PARAMETER REALIZATIONS FOR THE SCENARIOS

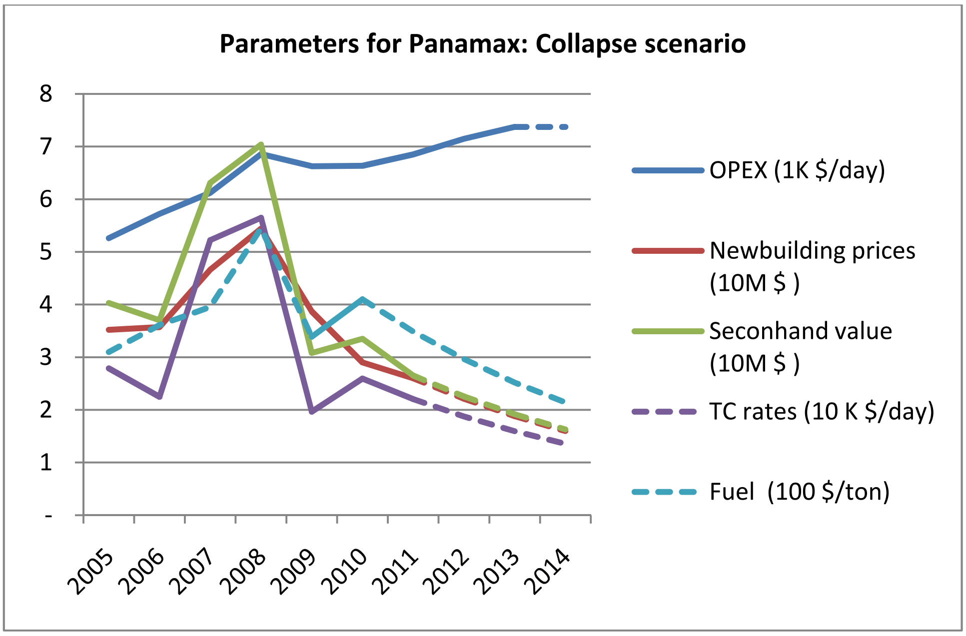

FIGURE 24 - RELATIONS BETWEEN PARAMETER DEVELOPMENTS FOR COLLAPSE SCENARIO

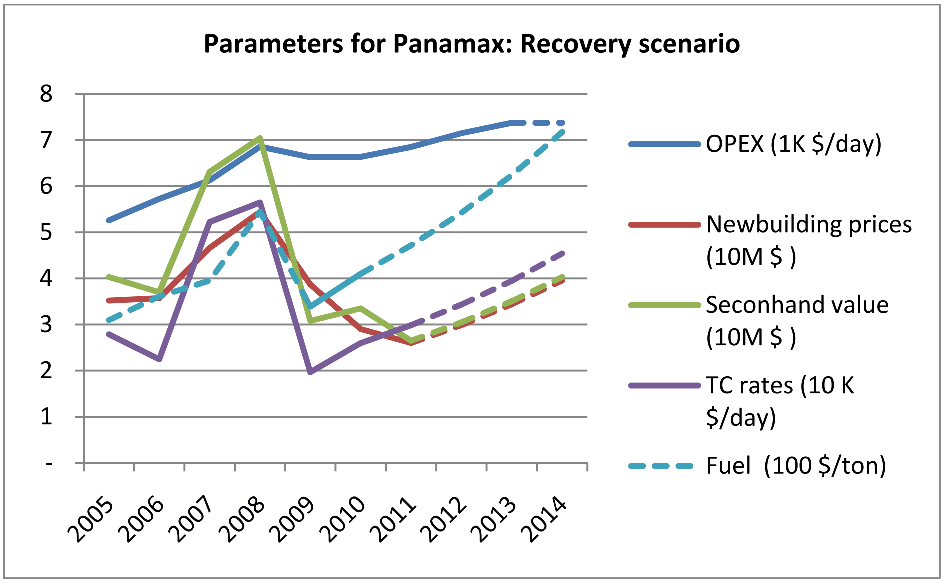

FIGURE 25 - RELATIONS BETWEEN PARAMETER DEVELOPMENTS FOR RECOVERY SCENARIO

APPENDIX C

IMPLEMENTED MODEL AND INPUT DATA