USING GAME STRUCTURING METHODS TO ASSESS THE RELIABILITY OF THE DEPARTURE ORDER OF SEA-GOING CONTAINER SHIPS

TOM VAN DER SCHELDE
4002903

Alexander Verbreack
Scott Cunningham
Martijn Warnier
Pieter Nordbeck

Graduation Chair – Policy Analysis
First Supervisor – Policy Analysis
Second Supervisor – Systems Engineering
External Supervisor – Port of Rotterdam

TU Delft
Delft University of Technology

Faculty of Technology, Policy and Management

Port of Rotterdam

September 2015
The first meeting I had at the Port Authority regarding this thesis sprouted a rather unusual metaphor: ‘since we are all apes, it would be good if your thesis could point out where the bananas are for everyone’. My quest for this metaphorical fruit took over six months. It led me into the unfamiliar territory of the Port and Game Structuring Methods. It has been a tough but valuable experience. One that I could not have completed on my own.

Scott, thank you for not only pointing me towards a great opportunity in writing a thesis about delays in the port of Rotterdam, but also for all the times you offered me new perspectives and suggestions. Pieter, you have been a joy to work with you. Someone at the Port Authority described you as a ‘caterpillar’, a jack-of-all-trades. I could not agree more. Thank you for showing me around in the port and for your enthusiasm and support. Martijn, thank you for keeping me on track. Your practicality was sorely needed at times. Alexander, you have my gratitude for keeping in mind the bigger picture. Besides your help on this thesis, I would also like to thank you for the guidance and inspiration in other courses and projects during my time at TPM.

Next to the graduation committee there have been many people who either helped or showed great interest in the project. Special thanks go out to Ben van Scherpenzeel and Jacob Bac, who played a crucial role in the coming together of this document. You offered expertise and contacts within the port for me to draw upon. Thanks also goes out to all the people at the harbour master division, especially to Wim, Henk, Kees, Herm-Jan, Rob, Hanneke, Bert and Marius, who had to put up with me over the course of six months. You have made me feel very welcome. Elco Oskam, for allowing me to accompany him on a pilot trip. A great experience that also provided the photo for the cover of this document. I should also mention the staff and fellow students at TU Delft. Thank you for the great time I had during my six years there. Finally, I would like to thank my family and friends who were supportive and patient throughout my study. Especially during writing this thesis, when I was practically a recluse.

Delft,
September 25
2015
EXECUTIVE SUMMARY

Competitions between ports make that delays in ship handling are of growing concern in European ports and the Port of Rotterdam. Failure of coordination between the parties involved is said to be the main reason for delays.

Coordination failure is however a wicked problem, which implies that there is no agreement between parties on the exact problem or its solution. Moreover it is largely unknown between which parties coordination fails, why it fails, what the nature of the failure is and what the impact is. To decrease delays in ship handling in the port of Rotterdam this research applies a sub-set of problem structuring methods (PSM) to analyse coordination failure. This analysis leads to recommendation for improvement.

The research is scoped on a part of the ship handling process, based on three criteria:

- The part that results in the biggest delays
- For which data is available
- There where the Port Authority has influence.

By decomposing the ship handling system, it is found that the departure order process of sea-going containerships fits those criteria the best. The estimated time of departure (ETD) communicated for containerships is often found to be unreliable. There are multiple possible root-causes for that. This report investigates one of them with the main research question;

To what extent can incentives in terms of delay and cost of individual chain partners in ship handling explain delays in the departure process of sea-going container vessels in the port of Rotterdam?

To investigate that question, Game Structuring Methods (GSM) (which have a shared origin in game theory) are used. Specifically a Metagame analysis fits with this problem. To use that method the departure order process is described in terms of six elements; players, order of play, information, actions, outcomes and payoffs. By framing the departure order process as such, the influence of an action of a player on his experienced delay and cost can be investigated. It thereby is possible to research to what actions players are driven by their goals. To do that in a meaningful way, five strategic hypotheses are formulated to make the goal of the game more clear. These hypotheses are based on interviews with experts from several chain parties. Moreover, if all hypothesis are supported they provide an explanation for unreliable ETDs and thereby delays in ship handling.

The following strategic hypotheses are used:

- **Strategic hypothesis 1:** Container terminals have an incentive (expressed in time and money) to communicate an expected end-of-ops-time that is a low estimate of the end-of-ops-time they actually perceive to be true (i.e. communicate an unreliable ETD).
- **Strategic hypothesis 2:** Shipping companies have an incentive (expressed in time and money) to communicate an estimate time of departure that is lower than the ETD they actually perceive to be true (i.e. communicate an unreliable ETD).
- **Strategic hypothesis 3:** Shipping companies with smaller ships don’t have an incentive (expressed in time and money) to communicate an estimated time of departure that is lower than the ETD they actually perceive to be true (i.e. communicate an unreliable ETD).
• **Strategic hypothesis 4:** Other parties experience damage from unreliable departure orders, but their financial damages are relatively low. The incentive to counteract unreliable departure orders is thereby existent, but small.

• **Strategic hypothesis 5:** These incentives lead to unreliable departure orders, which result in Pareto optimal outcomes.

Subsequently the coordination in the departure order process is framed in the form of a ‘game’. The players in the game are; terminal, shipping company, shipping agent, port authority, pilot, tugboat company and boatmen. In this game the decisions available to the player in the game consist of manipulating the expected departure time (or not), before communicating that time to the next player in the process. Meanwhile information in the game is incomplete. This means that players do not know what the other player has done for certain, until after the player itself has acted. Because of these characteristics players can potentially communicate a time that they know not to be realistic, in the hope that other players act upon that time. The question is whether acting as such lead to better results for the player than if he does not manipulate the departure time.

By making some assumptions on what time scale the players manipulate the ETD and on when the cargo operations are finished, the effects of actions on the delay that players experience can be quantified. This mathematical model takes into account the relative position (smaller, equal or higher) between the received and communicated time as well as technical limitations (i.e. a ship cannot depart before the end of cargo operations time).

The effects of actions on the cost experienced by players is calculated by multiplying the delay these players experience (in hours) with the delay cost per hour and some cost parameters reflecting penalties parties charge each other. Most importantly, the delay cost per hour for a player are assumed to be equal to the opportunity cost of that player (the revenue a players has per hour).

To then generate the outcomes that are required for testing the strategic hypothesis, both mathematical models (for cost and delay) are translated into a simulation model. With this simulation model, all possible combinations of actions and input variables are simulated.

**Analysis of the simulation outcomes show that strategic hypothesis 1, 4 and, 5 can be supported, while strategic hypothesis 2 and 3 must be falsified.** Although the model does show that shipping companies have a time-based incentive to communicate unreliably. Moreover, different experts supports that shipping companies are likely to act according to this incentive.

The validation of the model and its conclusions is split up in three parts. The game itself can be seen as an accurate representations of reality. It shows a variety of situations, and takes into account that the departure order process is influenced by the rest of the ship handling process. The building blocks of the game are all validated by experts or based on data from the Rotterdam Port Authority. Secondly, the conclusions that follow from the model are robust for large parameter changes and confirm most of the strategic hypotheses formulated earlier. Lastly, the model seems to have some internal validity. There are definitely variables and behaviour that cannot be explained by the model. In particular, ‘softer’ variables such as trust or parties favouring regular clients are not included. At the same time it is entirely believable that these parties will consistently pursue mostly low cost and delay. It seems reasonable to say that in most cases cost and delay as expressed in the model explain the behaviour of the players. There are several experts who support this believe.

The internal validity however can never be proven. Nonetheless, the model can still be of use. It presents a case that is apparently valid too such an extent that it creates commitment to action. Providing a well-argued case that (the potential for) strategic
behaviour is present creates a platform for dialog and allows for (pre-emptive) counter measures. This clearly has value, given that the model provides an explanation for unreliable departure orders and related delays.

The research also provides insight into what can be done by the Port Authority to decrease unreliable ETD’s and thereby delays and costs in ship handling. Weighting their effectiveness and feasibility the following measures are recommended;

- Expand the departure order to include the ‘end of cargo operations time’ that shipping agents receive from terminals
- Introduce a ‘most reliable terminal and shipping company of the year’ title, including financial incentive.
- Subsidize unprofitable capacity of Nautical Service Providers
TABLE OF CONTENTS

Preface ................................................................................................................................. ii
Executive summary .................................................................................................................. iii
1. Introduction ......................................................................................................................... 2
  1.1 Delays in ship handling................................................................................................. 2
     1.1.1 European ports....................................................................................................... 2
     1.1.2 The port of Rotterdam........................................................................................... 4
  1.2 Impact of delays............................................................................................................. 4
  1.3 Problem statement......................................................................................................... 5
  1.4 A wicked problem ....................................................................................................... 5
  1.5 Objective and perspective............................................................................................ 7
  1.6 Preliminary research question...................................................................................... 7
  1.7 Deliverables.................................................................................................................. 7
  1.8 Social and scientific relevance....................................................................................... 8
  1.9 Structure of the document............................................................................................ 8
2. System conceptualisation .................................................................................................... 10
  2.1 Low hanging fruit ....................................................................................................... 10
  2.2 Largest delays............................................................................................................. 10
  2.3 Data analysis ............................................................................................................... 11
     2.3.1 Severity of delays................................................................................................. 11
     2.3.2 Coordination failure............................................................................................. 12
     2.3.3 Container ships.................................................................................................... 14
     2.3.4 Implications for Research scope.......................................................................... 15
  2.4 Significance of delays................................................................................................... 16
     2.4.1 Costs for shipping companies.............................................................................. 17
     2.4.2 Costs for other parties.......................................................................................... 18
  2.5 Ship handling process ................................................................................................ 18
     2.5.1 Chain parties........................................................................................................ 18
     2.5.2 The changing arenas of the ship handling process............................................... 19
  2.6 Influence of the Port Authority..................................................................................... 22
  2.7 Problem scoping.......................................................................................................... 24
     2.7.1 Reliability of departure orders............................................................................. 24
     2.7.2 Main research question......................................................................................... 25
3. Research approach ........................................................................................................... 28
  3.1 Requirements................................................................................................................ 28
  3.2 Problem structuring methods....................................................................................... 29
     3.2.1 History.................................................................................................................. 29
     3.2.2 Current state of PSMs .......................................................................................... 29
  3.3 Method Selection........................................................................................................... 30
     3.3.1 Available methods............................................................................................... 30
     3.3.2 Method characteristics.......................................................................................... 30
  3.4 Conceptual design......................................................................................................... 33
     3.4.1 Framework that will be used................................................................................. 33
     3.4.2 Use of the framework ......................................................................................... 33
  3.5 Related work ................................................................................................................ 34
     3.5.1 Applied game theory............................................................................................. 34
     3.5.2 Applied to supply chains....................................................................................... 34
     3.5.3 Applied to The Ship handling ............................................................................ 34
4. Departure order game ................................................................. 36
  4.1 Goal of the game ................................................................. 37
    4.1.1 Strategic hypotheses ....................................................... 37
    4.1.2 Interventions to research ............................................... 38
    4.1.3 Intervention strategy ...................................................... 38
  4.2 Boundary conditions ........................................................... 38
  4.3 Players .................................................................................. 41
    4.3.1 Terminal ........................................................................... 41
    4.3.2 Shipping company ........................................................... 41
    4.3.3 Shipping Agent ............................................................... 42
    4.3.4 Port Authority ................................................................. 42
    4.3.5 Tugboat companies .......................................................... 43
    4.3.6 Pilots ................................................................................ 43
    4.3.7 Boatmen ............................................................................ 43
  4.4 Order of play .......................................................................... 43
  4.5 Actions and information ......................................................... 44
    4.5.1 Who knows what, when? .................................................. 44
    4.5.2 Scenarios .......................................................................... 45
    4.5.3 Steps in departure order process ....................................... 46
    4.5.4 Acting on order ............................................................... 48
  4.6 Outcomes ................................................................................ 50
    4.6.1 Delay ................................................................................. 50
    4.6.2 Costs ................................................................................. 52
    4.6.3 Theory versus reality ....................................................... 52
  4.7 Payoffs ................................................................................... 54
  4.8 Implications for simulation model ......................................... 55
5  Simulation .................................................................................... 56
  5.1 Simulation tool ....................................................................... 56
  5.2 Implementation ...................................................................... 56
    5.2.1 Elements of the game ....................................................... 56
    5.2.2 Translating mathematical models to simulation model ....... 56
    5.2.3 Experimental design ......................................................... 59
  5.3 Verification ............................................................................. 60
6  Simulation outcomes ................................................................. 62
  6.1 Incentives terminal ............................................................... 62
  6.2 Incentive shipping company .................................................. 65
  6.3 Incentives other players ......................................................... 67
  6.4 Sensitivity .............................................................................. 69
  6.5 Value creation ....................................................................... 71
7  Validation .................................................................................... 72
  7.1 What should be validated ....................................................... 72
  7.2 validating game structuring methods ...................................... 72
  7.3 Game ....................................................................................... 73
  7.4 Analysis of outcomes ............................................................. 75
  7.5 behaviour in reality ............................................................... 76
  7.6 Conclusion and model use ..................................................... 77
8  Changing the game ..................................................................... 80
  8.1 Change of moves ................................................................. 80
8.2 Change of Value sharing ................................................................. 80
8.3 Change of Information ................................................................. 82
8.4 Proposed measures ...................................................................... 84
8.5 Further research .......................................................................... 85
8.6 Lessons learned ........................................................................... 86
9 Conclusions and Recommendations .............................................. 88
10 Reflection and Discussion ............................................................. 92
  10.1 Generalisable findings ............................................................... 92
  10.2 Game structuring Methods ........................................................ 92
References .......................................................................................... 94
Appendix A: Main and sub categories of delay .................................... 99
Appendix B: Delay influence tables .................................................... 100
Appendix C: Actions of players .......................................................... 102
  Steps in departure order process .................................................... 102
  Acting on order ............................................................................. 105
Appendix D: Possible Games ............................................................. 108
  Tugboat competition “Competition versus service” ......................... 108
  Tugboat capacity arrangement ...................................................... 109
Appendix E: Delay matrix calculations .............................................. 112
Appendix F: Cost parameter calculations ........................................... 116
  Terminal Cost ............................................................................... 118
  Shipping company delay cost ....................................................... 118
  Shipping Agent delay cost ............................................................ 119
  Port Authority delay cost .............................................................. 119
  Pilot delay cost ............................................................................ 119
  Tugboat Company delay cost ....................................................... 121
  Boatmen delay cost .................................................................... 122
Appendix G: Netlogo Code ............................................................... 124
Code 124
  Experimental design ..................................................................... 147
Appendix H: Simulation model results .............................................. 150

List of figures
Figure 1: Envisioned coordination structure in the Pronto project .......... 3
Figure 2: Process of ship handling and registration of delays ............... 5
Figure 3: Structure of the document and most important inputs .......... 9
Figure 4: Main cause of delay unfiltered ......................................... 12
Figure 5: Type of goods that are delayed unfiltered .......................... 13
Figure 6: Main cause of delay without ‘external influences’ ............... 14
Figure 7: Main causes of delay for container ships ......................... 15
Figure 8: Ship size versus delay ....................................................... 16
Figure 9: Delay duration containership versus ship size ................... 16
Figure 10: Process decomposition ................................................... 20
Figure 11: Formal relation diagram .................................................. 21
Figure 12: Formal influence trees .................................................... 22
Figure 13: Delay influence diagram ................................................ 23
Figure 14: Delay influence network diagram ................................... 24
Figure 15: Delay influence diagram departure order process ............ 25
Fig. 16. Inventory of PSMs based on Cunningham et al. [2015], figure 1, p.7 ........ 31
Figure 17: Relation between chapter 4, 5, 6 and 7........................................................................ 36
Figure 18: Process diagram of coordination process for the departure of a ship .... 40
Figure 19: System diagram of departure order game................................................................. 41
Figure 20: Mockup graph of simulation outcome............................................................................ 54
Figure 21: Simulation model interface.......................................................................................... 57
Figure 22: Animation steps ........................................................................................................... 58
Figure 23: Influence of terminal’s choice.................................................................................... 62
Figure 24: Comparison of paths.................................................................................................... 63
Figure 25: Influence of Shipping Company’s choice ................................................................. 65
Figure 26: Inferred relation game and behaviour in reality....................................................... 72
Figure 27: Example chance distribution time of a terminal.............................. 74
Figure 28: Game tree with incomplete information ............................................................ 83
Figure 29: Game tree with information sharing ................................................................. 83
Figure 30: Sub-causes of delay ............................................................................................... 99
Figure 31: Delay influence diagram magnitude of delay .................................................. 100
Figure 32: Delay influence diagram influence Port Authority .............................................. 100
Figure 33: Network diagram tugboat competition ............................................................. 108
Figure 34: Network diagram capacity arrangement ............................................................. 110
Figure 35: Departures of containerships from Port of Rotterdam ............................................. 120
Figure 36: Vessel track on www.Marinetraffic.com .............................................................. 121
Figure 37: Pilot boat circling at Maas Center Buoy on www.marinetraffic.com ..... 121
Figure 38: Influence of Port Authority’s choice ................................................................. 150
Figure 39: Influence of Pilot’s choice .................................................................................... 150
Figure 40: Influence of Tugboat company’s choice.......................................................... 151
Figure 41: Influence of Pilot’s second choice ................................................................. 151
Figure 42: Influence of Tugboat Company’s second choice............................. 152

List of tables

Table 1: Input scenario variables ................................................................................................. 46
Table 2: Players and their actions ................................................................................................. 51
Table 3: Single strategy profile of the game .................................................................................. 51
Table 4: Delay matrix .................................................................................................................. 52
Table 5: Actions taken in experiment .......................................................................................... 59
Table 6: Communicated times in experiment ............................................................................. 59
Table 7: Delay experienced in experiment .................................................................................. 60
Table 8: Cost experienced in experiment .................................................................................... 60
Table 9: Frequency table shipping company outcomes ............................................................ 65
Table 10: Frequency table Port Authority Outcomes ............................................................... 68
Table 11: Frequency table Pilot outcomes................................................................................... 68
Table 12: Frequency table outcomes Tugboat company ......................................................... 69
Table 13: Outcomes with stochastic operations time ............................................................ 74
Table 14: Creation of value by changing behaviour................................................................... 81
Table 15: Influence of players on system.................................................................................... 83
Table 16: Different sections of delay matrix ............................................................................... 112
Table 17: Delay cost in euro per hour ......................................................................................... 116
Table 18: Delay cost matrix (experienced cost in euro per hour).............................................. 117

Used abbreviations:
AEoOT: Actual End of Operations Time
ATD: Actual Time of Departure
EEoOT: Expected End of Operations Time
ETD: Expected Time of Departure
DWT: Dead Weight Tonnage
GSM: Game Structuring Method
NSP: Nautical Service Providers
O.R: Operations Research
PSM: Problem Structuring Method
1. INTRODUCTION

Delays in ship handling are of growing concern in European ports and the Port of Rotterdam. Failure of coordination between the parties involved is said to be the main reason for delays. However, a structured analysis of coordination failure has not been done at the Port Authority. It is a subject worth studying, given the impact of delays. Yet, it is to a large extent unclear how and why coordination between parties fails and how to deal with it. This chapter frames delays in ship handling as a ‘wicked’ problem and explains that Problem Structuring Methods are suited to deal with such problems. This research sets out to formulate recommendations for the Port Authority to improve the total ship handling time and cost for all involved parties. The last few paragraphs describe the research question that needs to be answered, the deliverables that will result from the research, the relevance of those deliverables and finally the structure of the rest of the report.

1.1 DELAYS IN SHIP HANDLING

1.1.1 EUROPEAN PORTS

Competition between ports in Europe increases [Logistiek, 2013; Port of Rotterdam, n.d.]. To stay competitive, ports continuously must improve their efficiency and capacity with regard to ship handling [Het Schip Centraal, 2013]. The Port (authority) of Rotterdam for example has the ambition to have doubled their handling capacity in 2030 [Giarte, 2014]. Ship handling in this paper is understood as all activities related to bringing a ship into a port, off-loading its cargo, servicing it and navigating the ship out of the port again.

To improve the competitiveness of a port it is crucial to reduce (unplanned) delays in the logistical (supply) chain of ship handling. The total delay in the port of Rotterdam was around 310,000 hours in 2010 (equivalent to 35 years) [Giarte, 2014]. This delay can mostly be accounted for by the interaction of the several parties involved [Roo, 2014]. The different parties have optimised their own internal business processes.

In this light, the biggest improvement can be achieved by focussing on improving the coordination between the several parties involved in ship handling. At the same time a growing port often means increasing the complexity of coordination tasks. An example of that can be found in the port of Rotterdam. Recently the second Maasvlakte, an extension area to the port has become operational. This puts coordination in ship handling under pressure through an influx of new parties, bigger ships and longer shipping lanes [Port of Rotterdam, 2011]. These new parties for example include container terminals, which are in competition and therefore not immediately inclined to coordinate with each other.

Meanwhile, the capacity of tugboats and pilotages is put under pressure by the longer shipping routes and increased number of parties. The increased attention of the Dutch competition authority into the practice of tugboat companies that rent tugboats from their competitors during ‘peak-moments’ also contributes to that [Het Financieele Dagblad, 2014; Schuttevaer, 2014].

Coordination between parties in this context is difficult and will fail from time to time, counteracting the efforts for more efficient ship handling. Parties involved in the port of Rotterdam have agreed earlier upon that coordination in ship handling was an issue [Het Schip Centraal, 2013]. In a brochure of a project called ‘The Ship Central’ several parties emphasise the importance of good coordination. The brochure quotes spokespersons of the involved companies, providing anecdotes about situations in which coordination fails.

One example of coordination failure can be described on the basis of an interview done by the Port of Rotterdam Authority with a tugboat company [Nordbeck, 2014e]. During times in which capacity arrangements of tugboats are in effect (tugboat companies announce that they don’t have enough capacity to meet the planning) ship handling usually
goes in a chaotic ‘first come, first served’ manner. Pilots on board of ships then have to make a decision whether they continue their route to the berths, hoping that tugboats are available or to stay at sea. The parties make these decisions independently from each other, leading to delay in the whole chain of ship handling. The issues that these anecdotes point out can be generalised and summarised to the following:

- Unreliability of agreements between different parties about the communication of arrival and departure times.
- Inaccuracy of information.
- Parties signalling other parties to act too soon.
- Clashing interests of parties.
- Parties that are not included in the coordination process, while other parties are dependent on them.
- Last moment changes in the planning of one party affect the planning of others.
- Ad-hoc way of working.
- The willingness to share information with other parties (competitors) [Nordbeck, 2014a, 2014d].
- Parties favouring their big clients [Nordbeck, 2014b; Rootselaar, 2014].

The port of Rotterdam is actively pursuing a reduction of these issues, by for example sponsoring the development of a social business communication platform called Pronto [GS1 Denmark and GS1 Hungary, n.d.]. This platform allows for sharing and receiving of information regarding the planning of all services related to ships. It rearranges how coordination is carried out between parties. A shipping agent no longer has to gather information from multiple service providers, instead he can access Pronto for that information (see figure 1, which is adopted from GS1 Denmark and GS1 Hungary [n.d.]). Other examples are increased attention to assessment of coordination and efforts to reduce the amount of rules on ship handling activities [Het Schip Centraal, 2013].

While these efforts have potential to reduce coordination failure and decrease delays, they do not address all the earlier identified issues. Moreover the named endeavours require the support of the many parties involved in ship handling [Port of Rotterdam, 2011], which in turn requires a (to some extent) shared understanding about the reasons for coordination failure. This context emphasises the value of an analysis into why, when and how coordination in ship handling fails. Similarly there is also value into an analysis how coordination can be improved and what the benefits of that improvement will be for individual parties.
1.1.2 THE PORT OF ROTTERDAM

Except for the anecdotal evidence referred in the previous chapter, not much is publically known about coordination failure in the port of Rotterdam. Considering that efficient and effective ship handling is something ports compete on, it is unsurprising that (sensitive) information about failures in coordination is not made public. However, even within the Port Authority, a thorough and structured analysis of situations in which coordination failure occurs is not found in documents (that are known to the author).

As mentioned before, there are several documents which acknowledge that effective coordination between parties involved in ship handling is a requirement for decreasing delays. The emphasis in these documents is however on solutions rather than problems. The ‘scheepvaartverkeervisie haven’ (port shipping traffic vision) for example depicts an image on how ship handling should be done in the future [Port of Rotterdam, 2011]. One of the objectives it describes is that Port information should be available in a transparent way. Likewise the Pronto project, referred in the previous paragraph, aims to unify information streams between parties. This implicitly assumes that coordination can fail because parties do not have the same information (which in itself is not a shocking conclusion, but perhaps only one of the many causes). The underlying problem analysis to these solutions seems to be undocumented, missing or tacit knowledge of those that are involved in ship handling.

The omittance of documenting in a structured way what goes wrong with the coordination between parties and more specifically, why things go wrong, could lead to the emergence of many different understandings on why coordination between parties in ship handling in the Port of Rotterdam fails. Considering that coordination in ship handling and the underlying logistical (supply) chain is incredibly complex, it would be beneficial to have a more shared understanding about it.

1.2 IMPACT OF DELAYS

To determine the relevance of an analysis into ship handling coordination issues, the impact of these issues have to be assessed. The amount of attention given in documents and projects to reducing delays in the ship handling chain suggests that the effect on parties is big, but quantifying it is difficult. For example, how should we express the impact of coordination failure? In hours of delay or in delay cost and for whom?

The Port Authority has been registering time of delays of sea-going ships occurring in ship handling since 2013. This data can be used to estimate the impact of delays. This registration however provides a skewed picture on where delays take place, and the severity of the delays. Namely, the data only takes long delays (>30 minutes) into account, the registration only shows delays that took place in a part of the ship handling process and it underrepresents certain causes due to the way the delays are registered. Figure 1 shows in what part of the process of ship handling delays are registered. Also note that delays are not always caused by coordination failure, weather circumstances or internal business processes can just as well be a cause for delays. Some of these last causes however can be filtered out of the data.

Gathering new data in all likelihood will be difficult, given that data ownership is spread and the data is sensitive to businesses. Although the available data has its limitations, it can help setting a more narrow scope and support a research within that scope. Therefor the next chapter describes further analysis of the data.

To illustrate the impact of coordination failure; the delay registration shows that the delay for container ships from September 2013 to February 2015 accounts to 2341 hours (with external influences such as technical defects filtered out). Maersk Shipping line estimates the average cost of an hour of delay to be €3500 (B. van Scherpenzeel, personal communication, 13, March, 2015). A very rough estimate of the economic cost of
coordinated failure for shipping companies would then be €8.5 million over a period of one-and-a-half year. The ship handling chain however can be considered to be a part of many different supply chains, therefore delays in the nautical chain can cause delay (costs) elsewhere. At the same time parties experience delays differently, some parties could actually profit from the existence of a certain slack in the ship handling process. The actual impact is very much dependent on the situation (type of ship, actor that pays, how tight processes are coupled, etc.), nevertheless the estimation definitely warrants a research into coordination failure.

**Process of Ship handling**

1.3 PROBLEM STATEMENT

The previous paragraphs make clear that it is largely unknown (or at least undocumented) between which parties coordination fails, why it fails, what the nature of the failure is and what the impact is. As a result, it is also unclear how delays caused by coordination failure can possibly be solved. This leads to the following problem statement:

_How can we deal with the complex coordination issues in ship handling that the Port of Rotterdam is facing?_

The next paragraph introduces a family of methods that could be used to address this question.

1.4 A WICKED PROBLEM

The participants in the project ‘Het Schip Centraal’ explicitly state the goal for the Port of Rotterdam to be the best and most efficient European port [Het Schip Centraal, 2013]. Traditional Operational Research (O.R.) meanwhile is a discipline that often is employed to find optimum solutions to problem situations. It deals with the application of advanced (mostly mathematical) analytical methods to support decision making [INFORMS, n.d.].

The interdependency of parties, the complexity of coordination tasks, the nature of coordination and the characteristics of the parties involved however cause that coordination failure in ship handling can be defined as a wicked problem situation and
subsequently traditional O.R. will fail [Ackoff, 1979; Checkland, 1983; Rittel & Webber, 1973]. In wicked problems there is no agreement on the exact problem, cause or its solution. Similarly, in ship handling parties have their own, sometime conflicting objectives, and perspectives on why coordination between parties fails. A terminal for example desires that its berth has as little idle time as possible, minimizing the downtime of a berth however could mean that ships have to queue. Understanding coordination between parties in ship handling in this way implies that coordination cannot be optimised, as different parties have different perspectives on where the optimum lies. Moreover the characteristics of the institutional environment of the Port of Rotterdam (i.e. no hierarchy or a single market leader) emphasise the need to finding solutions for coordination failure that are broadly supported.

Any attempt at analysing coordination between different parties must thus be capable of taking different perspectives into account. Problem Structuring Methods (PSM) are an extension to O.R. that are more suited to deal with wicked problems. These methods retain the defining features of O.R. such as rational analysis and modelling [Jackson, 2005]. PSMs “aim for exploration, learning and commitment rather than optimization” [Mingers, 2011]. They have the following characteristics; [Cunningham, Hermans, & Slinger, 2015; Mingers & Rosenhead, 2004; Rosenhead, 1996, 2006]

- Participative and interactive.
- Capture different perspectives of a problem.
- Enable simultaneous consideration of several alternative perspectives.
- Accessible to actors without specialist training.
- Operate iteratively, reflecting state and stage of discussion among actors.
- Allows closure when participants are satisfied, this does not have to be when a global solution is achieved.

Chapter 3 will discuss a sub-set of PSMs (called Game Structuring Methods) that will be used to analyse coordination failure in the context of ship handling in the Port of Rotterdam. This sub-set has a shared origin in game theory. Game theory is the study of strategic interactive decision making. Situations in which decision-makers are conscious of the fact that their actions affect each other are modelled in a ‘game’. For the readers that are not familiar with game theory and its use, the following paragraph from Rasmusen [2001] explains it very shortly;

“The essential elements of a game are players, actions, payoffs, and information, PAPI, for short. These are collectively known as the rules of the game, and the modeller’s objective is to describe a situation in terms of the rules of a game so as to explain what will happen in that situation. Trying to maximize their payoffs, the players will devise plans known as strategies that pick actions depending on the information that has arrived at each moment. The combination of strategies chosen by each player is known as the equilibrium. Given an equilibrium, the modeller can see what actions come out of the conjunction of all the players' plans, and this tells him the outcome of the game”

Game theory can thus serve as a theory on how the coordination between ship handling parties takes place. GSM use the same basic principles of game theory but there are some nuances in how a situation can be modelled and what the method is generally used for. Chapter 3 further explains this, but for now it will suffice to understand that this thesis takes a game theoretic-like perspective on the coordination between ship handling parties.
1.5 OBJECTIVE AND PERSPECTIVE

The ultimate objective of this research is to formulate recommendations for improvement of coordination in ship handling in the Port of Rotterdam. What constitutes an improvement? One could take the perspective on ship handling delays that only considers (the reductions of) the attribute of ship handling time of different parties. That perspective could lead to the identification of points in the chain where improvements in terms of time can be achieved. It seems unlikely that this mono-attribute perspective would result in actionable recommendations for improvement because organisations care about more than reducing the ship handling time. Most importantly they care about the cost that have to make to achieve a certain reduction. The measure that would lead to the largest reduction in the total ship handling time is not necessarily feasible if the cost individual actors have to make for that measure are taken into account. Likewise, the benefits of a measure are (initially) not shared equal to the efforts of a party.

This document takes the perspective that coordination failure in ship handling is a multi-attribute, multi-actor problem situation. While the involved actors, among else care, about costs, emissions, safety and ship handling time, only the delay costs and delay time of parties and the chain as a whole are considered. Within this view the aim is to find win-win situation in which the total delay time as well as the total delay costs can be reduced in a way that parties can agree upon.

1.6 PRELIMINARY RESEARCH QUESTION

Taken the restrictions above into account, a first main research question can be formulated to guide the research. This question is preliminary because the research scope will be further narrowed down in chapter 2. The main research question is the following:

To what extent can the ship handling time and costs of ship handling parties in the port of Rotterdam be improved with recommendations resulting from a game structuring method-based analysis into the coordination choices of these ship handling parties?

1.7 DELIVERABLES

To be able to answer the research question, a Game Structuring Method framework will be used to (re)construct scenarios (or in GSM terms; ‘games’) in which coordination fails. These games take the form of matrices or decision trees and are accompanied by a story depicting the reasoning of the players that coordinate. This provides an inventory of structured analysis of coordination failure in ship handling. The next chapter scopes the research to a single case in which coordination fails, which will subsequently be described within a GSM framework.

The possibilities to change the elements of the games (players, rules, choices, outcomes etc.) and the effect of that change has to be studied to formulate recommendations for improvements. To be able to quantify those effects a simulation model, modelling the process on which the players coordinate on, is used. This simulation model will be part of the deliverables.

Regarding the kind and form of the recommendations, the recommendation will discuss what the Port Authority can do to achieve certain win-win situations. The feasibility of the recommendations, given legal, financial and stakeholder-relational (i.e. ‘is this
recommendation acceptable for all involved parties?”) constraints and possibilities will be discussed and considered, but not in great detail. A plan for action will also not be delivered.

1.8 SOCIAL AND SCIENTIFIC RELEVANCE

The desire for an analysis into coordination failure in ship handling and recommendations for improvement is shown by the projects already undertaken by parties in the port of Rotterdam. However, there is a broader social relevance to the research in the sense that some of the findings or the approach itself can be generalised to other European ports. Additionally, the findings can potentially be used in other multi-actor high tech supply chains, that also deal with increasing complexity of coordination.

The scientific relevance of the project proposal is partly formed by the fact that PSMs are deemed to be overlooked [Ackermann, 2012]. Since this research proposal is written in the context of a MSc. Thesis a publication is the aimed end-result. Moreover Cunningham et al. [2015] notice that the PSM field is skewed towards publications about qualitative PSMs. This project proposal focuses on the part of the field which is most deprived of publications.

On a more content related level, scientific relevance is derived from the fact that a Game Structuring Method approach to supply chain management is novel. A single instance of a PSM approach to supply chain management has been found during a literature research [Smith, Mackay, Altmann, & Gencoglu, 2002]. However, this text describes an application of Soft System Methodology, which is a PSM focussing on the system context, while GSMs focus on the decision context of a problem situation.

There have been several studies into the application of game theory (GSMs common origin) in supply chain management, but that body of research can be more considered to be part of the traditional O.R. field [Arshinder, Kanda, & Deshmukh, 2011; Cachon & Netessine, 2004; Hennet & Arda, 2008; Lozano, 2013; Reyes, 2005]. Its research questions are along the lines of; “what is the optimal configuration of partners in this supply chain?” or “what is the optimum production level of producer A?” These approaches implicitly assume that supply chain management is an optimisation problem. While some aspects could indeed be considered as such, this document framed coordination failure of ship handling parties as a wicked problem. As argued in the previous paragraphs this requires an approach such as GSMs.

1.9 STRUCTURE OF THE DOCUMENT

This chapter has explained that delays in ship handling in the Port of Rotterdam can be mostly attributed to coordination failure. The next chapter set the research scope on the departure order process of containerships. That scope is argued for by decomposing the ship handling system and analysing delay data. Subsequently, chapter 3 explores the research approach. There a specific GSM is selected that fits best with problem as set out in chapter 2. How that metagame framework can be used to answer the main research question is also explained. Chapter 4 specifies the elements of the GSM framework for the departure order process. To do that in a meaningful way, first some strategic hypothesis are formulated to make the goal of the game more clear. To calculate the delay and cost for individual parties in the departure order game, two mathematical models are made. To generate the required outcomes these models have to be translated to a simulation model. How this can be done is explained in chapter 5. These outcomes are analysed in the sixth chapter. Specifically, the strategic hypotheses formulated at the beginning of chapter 4 are tested. The validity of the game and its findings are dealt with thereafter. Chapter 7 expresses judgement on how accurate the game can represent the departure order process.
and moreover describes the use of the game. When validated, the findings in chapter 6 give rise to recommendations to reduce delays in ship handling. Chapter 8 discusses how the game can be changed to achieve that. The conclusions and recommendations are described in the chapter thereafter. The last chapter covers the reflection about the findings. Figure 3 visualises the structure of the documents and its most important inputs.
2. SYSTEM CONCEPTUALISATION

The goal of this chapter is to set a more narrow research scope. It describes the search for low hanging fruit, which meets three requirements (large delays, data availability and influence from the Port Authority). These requirements are depicted in paragraph 2.1. In this search the ship handling system is decomposed and analysed in terms of process, involved actors, formal and informal relations and delays that are caused. Paragraph 2.2 qualitatively describes where the biggest delays are present in the ship handling process. The next section provides an analysis of the delay registration of the Port Authority. Providing more insight in the size of the delays. The significance of the hours of delay that are shown in data is assessed in terms of cost in paragraph 2.4. The last requirement is tackled in paragraph 2.5 and 2.6 via a process decomposition, formal chart, influence trees and delay-influence diagram. The closing paragraph describes a game that fits the requirements of a low hanging fruit. The main research question is also formulated there.

2.1 LOW HANGING FRUIT

Projects such as Pronto and the ‘Het Schip Centraal’ have in common that they focus on reducing delays through improving coordination on the operational level of ship handling (i.e. improving reliable arrival and departure time), instead of the strategic level (e.g. what kind of contracts do shipping companies and towing companies agree with each other) [GS1 Denmark and GS1 Hungary, n.d.; Het Schip Centraal, 2013]. This research proposal will assume the same focus. This focus limits the research to the parties that are directly part of the logistical chain of ship handling (terminals, towing companies, pilots, etc).

Further narrowing down of this large number of organisations is required, given the timeframe of the research. Optimally, the coordination between the parties that results in the biggest delays is investigated, since the biggest improvements can potentially be achieved here. Furthermore, the availability of data on delays resulting from that coordination can show how significant the delays are. Lastly, given that this research is done in collaboration with the Port Authority, setting the scope on the coordination on which the Port Authority has influence is desirable. Such a scope will have the most chance of resulting in actionable recommendations for the Port Authority. The next paragraphs will describe a scope that meets these three requirements.

2.2 LARGEST DELAYS

To find the biggest delays in the ship handling process in the port of Rotterdam one has to resort to both a qualitative and quantitative analysis. As explained in the introduction, delays are only registered in a part of the process. This paragraph show the results of a qualitative analysis, the next will show those of the quantitative analysis.

Interviews with employees of the Port Authority and work done for the ‘Het Schip Centraal’ project have shed some light on where in the ship handling process the biggest causes for delays are placed [Port of Rotterdam, 2013]. These places are described below, together with some examples of why or how delays are caused.

Sea passage:
- Parties in the ship handling chain address that there are often unforeseen spikes in traffic relating to the fact that the estimated time of arrival of ships is wrong or unknown by parties.
- The Port Authority and some terminals have a first-come-first-serve policy that sometimes leads to a “photo-finish-race” to Rotterdam between ships at sea.
- Parties favour their big clients in planning.
Arrival readiness and clearance:
- It is not uncommon that ships are waiting for another ship to leave the berth.
- Terminal planning is not transparent.
- Tugboat capacity is put under pressure by longer shipping routes and increased number of parties.
- The estimated time of arrival of ships is wrong or unknown.
- Desired berths are not available.

Cargo and vessel operations
- Vessel service providers choose their own time to deliver their services.
- Terminal planning is often disrupted by delays of a service provider.

Departure readiness and clearance
- Tugboat capacity is put under pressure by longer shipping routes and increased number of parties.
- Shipping agents order a delay that is too ambitious.
- Cargo handlers ad hoc decide to take more cargo on the ship.

To be able to research ‘low hanging fruit’ the scope should focus on either one of these four steps in the ship handling process. Without data however, it is unclear how significant these delays are to parties, how large they are in general and which part of the delay is caused by coordination issues.

2.3 DATA ANALYSIS
The Port of Rotterdam Authority has been registering delays of sea-going ships occurring in ship handling since 2013. This registration however provides a skewed picture on where delays take place, and the severity of the delays. First of all, only delays longer than 30 minutes are taken into account. Furthermore, only the delays of ships are registered that take place after a shipping agent has ordered a departure (the time for which an agent orders a tugboat and pilot to unmoor the ship is considered to be the estimated time of departure, which is compared with the actual time of departure to calculate the delay). This means that certain service that could cause delays are unrepresented in the data, because they are placed more early in the process of ship handling. For example; repairs to a ship could cause large delays but are a likely thing to be done first. Because they are far removed from the moment an agent will order a departure, repair services could be underrepresented as a cause for delay. Lastly, for practical reasons delays are registered without taking into account that they could have been caused by a previous delay. A delay can travel through the ‘nautical chain’, meaning a delayed departure of a ship can cause a nautical service provider to be delayed for its next job. In that case the delay registration accounts the second delay to the nautical service provider, despite there is an argument to be made that it was not its ‘fault’.

Gathering new data in all likelihood is difficult, given that data ownership is spread and the data is sensitive to businesses. Although the available data has its limitations, it can help setting a more narrow scope and support a research within that scope.

2.3.1 SEVERITY OF DELAYS
Analysis of the available data on sea-going ships can tell something about how large the delays are, which parties are involved with delays and what type of ships are delayed the most. Figure 4 shows the distribution of main causes of delays over eighteen months (September 2013 – February 2015). Of the 4290 hours of delay registered in total, most delays are registered with cargo services, nautical service providers and vessel services as causes. Over that same period the berth registration data shows that 86979 ships have used a berth in the Port of Rotterdam. All these ships at one point in time had to depart,
which enables a comparison with the delay registration. The berth registration however includes all ships, including ships that are not really part of the ship handling chain as defined in chapter 1, such as yachts. Once these are filtered out, 80978 records remain. That means that 5.3 % of departing ships are delayed, with a delay longer than 30 minutes. The average delay registered is 1 hour and 4 minutes. For comparison, the average time a containership lays at a terminal berth, is 11 hours for 1500 TEU ships and 31 hours for 16000 TEU ships.

Data from September 1st 2013 - February 25th 2015

Filtering the aggregate delay data for the type of ship that is delayed provides interesting insights. In an eighteen-month period container ships were clearly the most delayed ships, accounting for 58% of the delays (see figure 5). In that same period 19814 container ships were registered at terminal berths, meaning that around 12% of all departing containerships were delayed for at least half an hour. This distribution of delay does clearly suggest that the scope can best be set on delay of containerships.

2.3.2 COORDINATION FAILURE

The registered delays are not necessarily caused by coordination failure between parties. An attempt has been made to filter out the technical defects. The database also includes cases in which there are restrictions to traffic due to strong winds or mist. During such circumstances a pilot could decide to order an extra tugboat ad hoc. There is an argument to be made that the delay in these cases is caused by external effects (weather), rather than the coordination between parties. On the other hand it could be said that parties can take measures to prevent delays due to influences from the weather. It is not entirely outside their influence. Should you choose to filter out these cases the resulting delays are depicted in figure 6. The data still includes delays that are not of interest for this research, namely delays caused by hiccups in internal business processes or by coordination between
parties not directly involved in the ship handling chain (e.g. trucking companies coordinating with terminals to transport cargo). There is unfortunately no way to filter these causes out of the data. However, it has been said that the delay can mostly be accounted for by the interaction of the several parties involved because the different parties have optimised their own internal business processes [Roo, 2014]. Two important observations from figure 6 that roughly the same distribution between main causes for delay can be seen in the filtered data and that the total delay is decreased by 300 hours compared to the unfiltered data (from 4290 to 3990 hours).

Figure 5: Type of goods that are delayed unfiltered
2.3.3 CONTAINER SHIPS

Figure 7 shows the main cause for delays for container ships. Again the ‘external influences’ have been filtered out of the data. Similar to the aggregate data, it shows cargo services, nautical service providers and occupied berths as big causes. The distribution in delays has shifted quite a bit. For example note that the delay for nautical service providers has decreased disproportionally (from 1144 to 348 hours) given the decrease in total delay (from 3990 to 2341 hours).

The delay registration also lists sub-causes of delay (Appendix A shows the sub-causes that accompanied the data, in Dutch). The biggest sub-cause to cargo services is shown to be related to cargo activities (contributes to 97% of cargo services). Because the delay registration has no sub-sub-causes of delay it raises the question why cargo activities lead to delays so often:

- Are the cargo activities unpredictable by nature?
- Is the ETD not up to date?
- Are the parties not communicating?
- Is the data registered in a way that gives an untrue picture of reality?
- Are parties acting out of self-interest?
- Other causes?

The answer remains hidden in the data and interviews with several employees of the Port Authority, a manager from the Pilots organisation and an operations manager from VOPAK agency have not led to a single answer. Paragraph 2.7 describes how this could be investigated further. Tugboat companies and pilots are the biggest sub-cause for delay within the nautical service delays (74% and 24 % respectively). The same as for delay due to
cargo activities, there are no sub-sub-causes given. Remarkably boatmen only cause a very minimal amount of delay. Lastly, the main cause of occupied berth is not split out into sub-causes. Thus insight into why a berth is occupied has to be gained through another way. Differences in containership types could perhaps also be an explanatory factor for delays. In figure 9 containership in the berth registration as well as the delay data are put in ‘bins’ of 50000 Dead Weight Ton (DWT), which reflects the size or capacity of a containership. What can be concluded from that graph is that larger containerships are delayed more often than their part in the berth data would explain. There does not seem to be a relation between the size of a containership and the duration of the delay it experiences (see figure 10).

![Data from September 2013 - February 2015](image)

**Figure 7: Main causes of delay for container ships**

### 2.3.4 IMPLICATIONS FOR RESEARCH SCOPE

The data clearly shows that containerships are the most delayed type of ship. Furthermore the main causes for delay are registered for nautical service providers, occupied berths and cargo services. Therefore the research scope should focus on containerships and address the coordination of parties related to at least one of these main causes to meet the first requirement set out in paragraph 2.1. Another variable that seems worth to consider in the scope is the size of containerships, given that this has an influence on the frequency of delay experienced.
2.4 SIGNIFICANCE OF DELAYS

With the distribution and extent of the delays made clear, the question is whether parties that are involved in ship handling deem them of importance. The commitment of parties to projects like ‘Het Schip Centraal’ shows that the delays are significant enough for them to spend recourses on it. Though quantification of the costs of delays and comparison with for example port dues would allow for a better estimation of the importance of reducing coordination failure.

Figure 8: Ship size versus delay

Figure 9: Delay duration containership versus ship size
The cost of a delay for a shipping company very much depends on the kind of ship that is delayed. Bulk ships often have long trips, ocean crossing trips, carrying goods that don’t lose their economic value very quickly. A couple of hours delay is not considered to be bad. Container liner ships meanwhile have tight schedules, made months in advance, of which deviation is costly. “The container shipping business has become very competitive, and profit margins have become very small.” [Notteboom, 2006]. With that in mind, the total amount of registered delay is most likely important for container shipping companies. But what are the costs for a delay of an hour for a container liner ship? This is quite a complex question, and the answer is very much dependent on the situation and the approach.

Notteboom [2006] splits the costs for a delay into opportunity costs and economic depreciation of the cargo. “An extra day at sea creates opportunity costs linked to fixed capital and could lower the economic value of the goods concerned. The average value of containerised goods differs substantially among trade routes (see example in Table 4). A delay of one day incurred by a container load with a value of €40,000 typically results in the following costs: (1) opportunity costs (3%–4% per year)= €3–4.5 per day and (2) economic depreciation (typically 10%–30% per year for consumer products)= €10–30 per day. One day of delay with a post-Panamax vessel carrying 4,000 full TEUs from the Far East to Belgium thus implies extra costs on the goods of at least €57,000 (at 3% opportunity cost and 10% depreciation), which is much higher than the charter rate per day for a post-Panamax container ship (at present around USD 40,000 per day). The costs of delays imposed on the cargo could even be more elevated in case major disruptions take place in a production line due to late delivery of containerised raw or semifinished products. As such, delays in the maritime leg of the chain have an impact on the total door-to-door transit time, which is built into the supply chain inventory model. The shipping and transport markets have developed pricing mechanisms to anticipate expected delays (e.g. congestion surcharges) or to price delays ex-post (demurrage fees).”

Another approach is given in a Cost Benefit Analysis study into the broadening of the Maas gully [RIGO, 2009]. In this study the cost of a delay are split out into the cost of a ship (charter costs) and the cost of the cargo. Based on an earlier done logitmodel by Blauwens en Van de Voorde (1988) the time value of a TEU cargo as €2 per hour is estimated (based on an average value of goods in a TEU of €24000). Subsequently the cargo delay cost for an hour delay of a 7700 TEU ship is calculated as €2 times the average load percentage of 75% times 7700 TEU, equalling €11500 cargo costs. The charter cost are estimated to be €1208. Meanwhile in the approach from Notteboom [2006] the hourly cost for a delay are 57000 / 24 = €2375. Partly the difference will be due to the fact that a different ship is taken into consideration (4000 TEU vs. 7700 TEU) and another reason will be the underlying assumptions. It is not clear which approach resembles the true costs of shipping companies (if they do at all).

A representative from Maersk shipping line has estimated the average delay cost for their ships as €3500 per hour. At the same time he emphasised that the situation is very important, the delay cost can range to €10000 per hour, depending on the type of ship and schedule. (B. van Scherpenzeel, personal communication, 13, March, 2015). This cost has been used in the first chapter of this thesis to roughly estimate the economic cost of coordination failure for container shipping companies (€3500 * 2341 hours = €8.5 million). This gives some idea of the importance of delays, but to really get a sense of the significance of the hourly cost of delays, a comparison of the port dues a ship has to pay in the port of Rotterdam can be made.

The CBA-study estimates the cost for a 7700 TEU ship with a draught of 15.5 and length of 300m. The MAERSK Lirquen comes close to these specifications, with a TEU capacity of 7450 [Containership-Info, 2015b]. The port dues that Maersk shipping company
would hypothetically pay is dependent on its gross tonnage of 88.237 and the tonnage of cargo it offloads. Similar to the example given in the general terms and conditions Port Dues, the tonnage that is offloaded is about 50% of the gross tonnage of the ship [Port of Rotterdam, 2015c]. The port dues are $88237 \times \€0.239 + 44185 \times \€0.475 = \€42000 \text{ (rounded)}$

The article from Notteboom [2006] estimates the cost for a 4400 TEU container ship. The MAERSK Brooklyn comes close to that specification with a capacity of 4300 TEU and a gross tonnage of 48800 [Containership-Info, 2015a]. The port dues for this ship, again assuming an offload tonnage of 50% of the gross tonnage, are $48800 \times \€0.239 + 24400 \times \€0.475 = \€ 23000 \text{ (rounded)}$.

In the first approach the delay costs per hour are about 30% of the port dues and in the other approach the delay cost form 10% of the port dues. If the container liner shipping business is indeed very competitive and profit margins have become very small, both percentages seem big enough to be deemed significant by shipping companies. In other words, container-shipping companies do have a real interest in dealing with coordination issues in the ship handling chain. This also supports a research scope focussing on container shipping companies.

### 2.4.2 Costs for other parties
A delayed ship will not only result in costs for the shipping company, but also for other parties in the logistical chain. These costs will not be estimated in this paragraph, because it is not yet clear which parties are involved, next to the shipping company. Moreover knowledge on whether the cost of a delay are large enough for other parties to care about reducing delays or not, is not necessary to set the research scope.

### 2.5 Ship handling process
The previous paragraphs showed which ships are delayed (container ships), what and which party causes the delay, and that the delays can be deemed significant. A decomposition of the ship handling process allows a better description of when ships are delayed and who else is involved in the coordination that leads to delays. Ultimately, this also allows for an assessment of the influence of the Port Authority on parties and the process (the Port Authority having influence is a requirement for low hanging fruit). This will be done in the next paragraph. First it will be made more clear who the involved parties in the ship handling process are and what they do.

#### 2.5.1 Chain parties
The short description of the several parties depicted below is partly based on the departed process description from Grund [2014].

**PORT AUTHORITY**
The Port Authority of Rotterdam can roughly be divided into two branches: the Port of Rotterdam PLC. and the Harbour Master division. The PLC is mainly responsible for “the development, construction, management and operation of the Port and industrial area in Rotterdam” [Port of Rotterdam, 2015b]. The Harbour master division is a department within the Port Authority that has public competences. The Harbour Master is the appointed (by national government and municipality of Rotterdam) authority with regards to safeguarding a safe and nautical efficient handling of shipping.

**SHIPPING AGENT**
Shipping agents handle practical issues, in the broadest sense of the word, that accompany the port stay of ships for one or multiple shipping companies. This includes communicating with the Port Authority and other service providers on behalf of shipping companies.

**PILOT ASSOCIATION**

Pilots provide navigational and advisory services to a captain on board of a ship in and near the Port area. These independent professional are organised in the Pilot Association. The pilots themselves have expertise in sailing with certain type of vessels, in a specific region of the port. Their services are crucial in providing safe entry and exit to the port. Most ships are obligated to make use of a pilot for their port visit.

**TUGBOAT COMPANIES**

To assist ships with (unmooring) and sailing at low speeds, tugboats are required. Tugboat companies offer their services to all shipping companies that require them. The Port Authority has the final say to what extent tug assistance is needed. This among else is dependent on the dimensions of the ship, the hydrological and meteorological circumstances.

**BOATMEN**

Ships need to be lashed to berths to ensure they stay in place. Boatmen assist with handling the lashings of a ship. To carry out their work they use both small boats and vans at the terminal berths.

**TERMINAL**

To load and offload cargo, ships moor at terminals berths. There, cranes pick up containers from the ship and place them on vehicles that drive the containers to stacks (or vice versa).

**SHIPPING COMPANIES**

Ships that visit ports are owned by shipping companies. These companies transport cargo for cargo owners.

**VESSEL SERVICES**

Ships need all kind of additional services in order to function. To give a couple of examples; bunker companies provide fuel, garbage boats collect garbage from the ship and there are also companies that provide provisions for a ship’s crew.

### 2.5.2 THE CHANGING ARENAS OF THE SHIP HANDLING PROCESS

Figure 10 shows a decomposition of the ship handling process, from the perspective of the ship. It also shows which parties coordinate at every step and briefly describes the role of the Port Authority. The interaction between these parties at a particular step in the process could be called an arena. At every step there could be multiple arenas in which parties coordinate about certain issues. The goal of this chapter is to set the scope on one of these sub-arenas. The red circle signifies that significant delays occur in a step (based on paragraph 2.2), while the green circle shows in which steps the delays are registered by the Port Authority. These circles reveal that the sixth step (in which departure readiness and departure clearance is gained) holds the most promise to contain a sub-arena that can be coined a low hanging fruit.
Figure 10: Process decomposition
Figure 11: Formal relation diagram
2.6 INFLUENCE OF THE PORT AUTHORITY

To be able to assess the influence of the Port Authority, the formal relations between the parties in the ship handling process is shown in figure 11. Meanwhile, the influence trees (figure 12) shows how the relations in the network diagram can be used to influence parties to change the outcome of a certain coordination process. The trees show that the Port Authority has either direct or indirect formal influence to every party. The extent of the influence of the Port Authority however does differ per party and per step. For example, it could be difficult to influence Pilots and Tugboats through the formal relations depicted in the trees. Informal conversations with the involved parties could prove more productive than the use of the instruments mentioned here.

To continue in the search for low hanging fruit, a coordinating cluster of parties must be found that causes a large amount of delays and on which the Port Authority can exert much influence. Expressing these dimensions (Delay causation and influence of Port Authority) per process step per actor cannot be done objectively, since delays are not registered in every process step and extent of influence is a difficult factor to measure. To limit personal bias the following steps have been carried out, in collaboration with Pieter Nordbeck (1st supervisor) and Jacob Bac (the project manager of the ‘Het Schip Centraal’ project).

Step 1. Find all the unique actors given the actors in the process decomposition
Step 2. Assess the magnitude of delays for every process step and the magnitude of delay that is caused by the actors in a process step
Step 3. Assess the influence of the Port Authority on the actors in the arena per process step
Step 4. Find the average magnitude of delay causation for every actor, given the arenas they participate in
Step 5. Find the average ability of the Port Authority to influence every actor, given the arenas the actors participates in
Step 6. Tabulate the average magnitude and influence for each actor
Step 7. Rescale these numbers so that the smallest is one and the largest is five
Step 8. Make a scatter plot
Step 9. Create quadrants on the scatter plot
Step 10. For each actor draw a line to one or two of their most consequential partners
Step 11. Add in a few extra lines to make a fully connected graph
Step 12. Tease out a handful of actors which are connected and mostly in the North-East quadrant
Step 13. Find out the arenas where all these actors work together
Step 14. Assemble necessary evidence for selecting between the sub-arenas given the problem description and the data
Step 15. Make the choice for a sub-arena

To assess the magnitude of delays and the extent of influence in step 2 and 3 five-point scales have been used. The scale for ranking the magnitude of delay is the following; (n.i.) not involved, (1) almost never, (2) incidentally, (3) sometimes, (4) often, (5) bottleneck. The influence of the Port Authority on parties was ranked; (n.i.) not involved, (1) influenced by party, (2) indirect influence through other party in the process step, (3) direct influence on broad requirements of how parties may act within process step, (4) Port Authority is co-decider of process step, (5) direct influence through formal contract with respective party. The resulting scatterplots (figure 13 and 14) show that only terminals are placed in the northeastern quadrant, though tugboat companies are right at the border. The consequence is that the sub-arena that is scoped should include at least one of these parties to be considered low hanging fruit. The next paragraph describes a sub-arena that meets all the requirements set out in the beginning of this chapter.

Figure 13: Delay influence diagram
2.7 PROBLEM SCOPING

Several interviews within experts from the Port Authority and with other ship handling parties have led to the identification of a few possible ‘coordination-sub-arenas (or games) to further elaborate in the thesis. The arena that will be further investigated (because it fits the description of low hanging fruit best) will be described here, the other arenas can be found in appendix D.

2.7.1 RELIABILITY OF DEPARTURE ORDERS

The ETD that container shipping agents order for a ship often turns out to be not realisable, resulting in parties waiting at the ship. As shown in paragraph 2.3, the largest part of the delays for containerships are actually registered for ‘cargo activities not finished’. This leads to, among else, a big decrease of the capacity of nautical services. Contrarily, in the bulk sector, cargo services are not registered that often. In that sector, the departure order is often send out when all cargo activities are done. Container liners however have a tight schedule to maintain and terminals constantly aim for maximising their berth utilisation, thus agents are pressured to send out the departure order as soon as possible. Interviews have led to the insight that there may be more root causes hidden within the data on delayed cargo activities.

One factor that could influence the reliability of the ETD of the departure order is the uncertainty of the duration of cargo activities at a terminal. Similarly, how and how often the ETD is communicated from the terminal to the shipping agent can also be of influence. Another explanation put forward by some interviewees is that parties might exert strategic behaviour in communicating the ETD, acting out of self-interest.

To be able to decrease delays in ship handling, more insight is needed in the root cause. This report will research the incentives of the parties involved in coordinating the
departure order and the rational responses to these incentives. It could perhaps show why delay is caused, or find that incentives of the parties are not to blame. The involved parties in this sub-arena are shown in figure 15. Note that there are no parties involved on which the Port Authority has little to no influence.

This chapter has shown that a research into the departure order of containerships has the biggest relevance in terms of caused delay, does not include the parties on which the Port Authority has little influence and lastly it is confined to the process step on which data is available. In short, it ticks all the boxes for a low hanging fruit. The resulting scope focuses on; The parties that are involved in coordinating the departure clearance and readiness of a sea-going container vessel.

![Figure 15: Delay influence diagram departure order process](image)

**2.7.2 MAIN RESEARCH QUESTION**

Now that a more narrow scope has been set, the preliminary research question from the previous chapter can be adjusted. The main research will be:

*To what extent can incentives in terms of delay and cost of individual chain partners in ship handling explain delays in the departure process of sea-going container vessels in the port of Rotterdam?*

A game structuring method analysis will be used to answer that question. That analysis also leads to recommendations for improvement. Note that chain-partners are the parties that are part of the logistical chain of handling a ship.

The main research question can be split out into the following sub-questions:

1. How do chain-parties coordinate and where does this coordination fail?
a. Who are the players?
b. Which actions do they have?
c. In what order do these actions take place?
d. What is the information that these players have?
e. What are the outcomes to which parties are driven by their payoffs?
f. Do these outcomes serve as an explanation for an unreliable ETD?

2. Can the identified coordination failure be validated?
   a. Is there evidence to support the outcome?
   b. Do chain partners deem the outcome probable?

These sub-questions will be answered throughout the rest of this document, they will however not be referred to explicitly up until chapter 7. That chapter summarises the answers and discusses the validity of them.
3. RESEARCH APPROACH

With a research scope set and a main research question formulated, the research approach needs to be further explored. First the need for a theory on actor behaviour that can facilitate multiple perspectives will be argued for. The solution is sought in a sub-set of Problem Structuring Methods. A brief overview of the history and current field of PSMs is given, after which the research field of game structuring methods is structured. In the next paragraph the problem situation is matched with a certain method. After that the framework that will be used is explained. At the same time an argument is made for the use of a simulation model. Lastly the approach is positioned in related research.

3.1 REQUIREMENTS

The previous chapter set the scope to the unreliable ETD that is the result of coordination of containership departure. The aim of the research is to investigate what behaviour leads to an unreliable ETD and hypotheses that incentives of parties lead to parties acting that way. Thus a theory on actor behaviour is needed. Since coordination in ship handling crosses organisational bounds, the analytical framework should be able to deal with multiple perspectives. Different parties do not always share the same knowledge, perspective or goals and as a result will not experience coordination in the same way. Some ship handling processes of different parties might be more tightly coupled than that of others. The definition of a delay is not the same for every party. A delay of 15 minutes is not experienced by tugboat companies as ‘bad’ or ‘too late’, while boatmen do experience it like that [Nordbeck, 2014c].

The analyst is in this case faced with the challenge to translate the experiences with coordination of various stakeholders into a shared understanding of where, why and how coordination fails. This translation should be able to show different perspectives as well as be communicable to actors with different professional backgrounds. A ‘common language’ is also needed because there is no clear hierarchy between parties. The insights gained about how to change coordination cannot be implemented unilateral, attention should be given how to collaboratively change coordination.

As explained in the introduction, the interdependency of parties, the complexity of coordination tasks, the nature of coordination and the characteristics of the parties involved cause that coordination failure in ship handling can be defined as a wicked problem [Ackoff, 1979; Checkland, 1983; Rittel & Webber, 1973]. In wicked problems there is no agreement on the exact problem, cause or its solution. Similarly, in ship handling parties have their own, sometime conflicting objectives, and they have their own perspective on why coordination between parties fails. For example, a terminal desires that its berth has as little idle time as possible, minimizing the downtime of a berth however could mean that ships have to queue. Understanding coordination between parties in ship handling in this way implies that coordination cannot be optimised, as different parties have different perspectives on where the optimum lies. Moreover, the characteristics of the institutional environment of the Port of Rotterdam (i.e. no hierarchy or a single market leader) emphasise the need to finding solutions for coordination failure that are broadly supported.

PSMs are an extension to O.R. that are suited to deal with wicked problems. The hypothesis of this thesis is that a subset of PSMs can be used to analyse the coordination failure that occurs for departing container ships. This is due to the fact that this subset also includes a scientific valid way to analyse and explain actor behaviour (game theory). It is a hypothesis because this thesis describes to my knowledge the first attempt to use this approach to tackle a coordination problem to a ship handling chain. The last paragraph of this chapter describes just how different this approach is from related research.
### 3.2 PROBLEM STRUCTURING METHODS

#### 3.2.1 HISTORY
Gaining insight into the historical context of PSMs is required to have an understanding of what PSMs are. Most of the more recent literature on PSMs begin their account on the history of the field in the 1970s or 1980s. This is right around the time of the ‘internal crisis of O.R.’ [Rosenhead, 2006]. Several of the pioneers of the O.R. field expressed harsh criticism on the use of O.R. in practice and academic world. Russell Ackoff for example stated “In my opinion, American Operations Research is dead even though it has yet to be buried” [Ackoff, 1979]. The debate about O.R. during this time led to the development of PSMs, and therefore it makes sense to take this as the starting point of a historic overview.

During the internal crisis of O.R. worries about the assumption behind standard OR techniques were expressed [Ackoff, 1979; Checkland, 1983; Rosenhead, 2006]. O.R. assumed that factors, goals and problems could be defined and described in advance, consensual and uncontested. Often a single optimal solution was the result. These foundations of O.R. were not always consistent with the real world. The existence of complex, or “wicked problems” [Rittel & Webber, 1973], directly contested these assumptions. These kind of problems required (Problem Structuring) methods that deal with “multiple actor, multiple perspectives, conflicts of interest, major uncertainties, and significant unquantifiable factors” [Cunningham et al., 2015].

#### 3.2.2 CURRENT STATE OF PSMs
The current field of PSM knows a wide variety of methods. Structuring them in a way is necessary to evaluate them in a more general way. This is difficult because “just as with the traditional operational research (OR) approach, PSMs developed pragmatically. That is, by and large they grew out of practice, and were only theorised and systematised at later stages” [Mingers & Rosenhead, 2004].

Cunningham et al. [2015] attempt to structure the field of PSMs, referring to an earlier attempt by Jackson and Keys [1984]. This earlier attempt structures PSMs along a system context dimension and a decision context. Difficulties in problem solving can be the result of decision makers and/or systems. Problems become more difficult to solve if multiple decision makers are involved for example. The system context leads to more difficulties if the system itself becomes more complex. [Cunningham et al., 2015] claim that PSMs can be structured by looking at which context (system or decision) they focus.

The problem description as set in paragraph 2.7 scopes the problem to result from a decision context. The unreliability of the ETD of departing ships is hypothesised to be due to the incentives of the coordinating parties. PSMs that focus on the decision context have a common heritage in game theory, therefor Cunningham et al. [2015] coin them game structuring methods. They define the subset of methods as follows; “set of applied methods for finding strategic elements that shape decision processes in a complex problem setting. Such elements include, but are not restricted to, players, actions, payoffs, outcomes and information.”

Throughout literature a distinction often is made between hard and soft PSM. Lei and Thissen [2009] clarify that harder PSMs constitute a more quantitative group of PSMs, while softer PSMs are more qualitative in nature. On this gliding scale game theory can be considered the quantitative extreme and anthropological and ethnographic methods as the qualitative extreme. This way of looking at the PSM field seems to overlap with the way Cunningham et al. [2015] structure the field.
Figure 17 is an adaption of a timeline used by Cunningham et al. [2015]. An inventory of soft PSMs was added to the figure to show how the PSM field could be structured. The original figure shows a development timeline for the game structuring methods, it went beyond the scope of this document to investigate the heritage of the soft PSMs. The inventory is in no way intended to be exhaustive. This thesis will also not describe the individual PSMs, for a full account see [Ackermann, 2012; Mingers & Rosenhead, 2004; Rosenhead, 1996].

### 3.3 METHOD SELECTION

GSMs is a broad family of methods. There is a need for further specification of the approach. This requires that the problem situation is matched with a certain method that has the best fit.

#### 3.3.1 AVAILABLE METHODS

Methods within the Game Structuring Methods ‘field’ have branched out over the years (see figure 16). There are many different methods, for different kind of problems and with different kind of outcomes. Selecting a fitting method is difficult as there are no comprehensive overviews of GSMs publicly available that could provide guidance in that search. More authors have struggled with this, so becomes apparent in a special issue on Problem Structuring research and practice [Ackermann, Franco, Rouwette, & White, 2014]. That issue lists eight challenges to the development of the PSM field, one of which is: “encouraging researchers to build on prior problem structuring research rather than continuously reinvent the wheel”. An effort was made to take up that challenge for this thesis.

An article from Lei and Thissen [2009] provides some help by listing a few game structuring methods and their related application areas, types of outcomes and type of design. The descriptions provided by these authors for the different methods are quite short though. To assess the usability of a certain GSM, several articles applying the methods have been studied. A discussion of several of these methods and their fit follows.

#### 3.3.2 METHOD CHARACTERISTICS

**ANALYSIS OF OPTIONS METHOD**

The analysis of options method is different from a classic game theory model in the sense that outcomes are constructed from the options of the different actors. “In a classic game theory model, the outcomes for the players need to be known in advance. In the prisoner’s dilemma, for example, for each of the players the outcomes are known if they confess to the crime or keep silent. Metagames are built with the analysis of options method. With this method, the outcomes are constructed from the options of the different actors. The outcomes are all possible combinations of the options minus the infeasible outcomes removed by the analyst. Because the outcomes are constructed with the analysis of options methods, the information demand is lower than that of classical game theory” [Lei & Thissen, 2009]. Howard [1987] even describes it as “a way of building a game model without applying any theory to it, and without even specifying players’ preferences”. The goal of the method is to support systematic analysis of strategic interactions.

Since the method does not include a theory on how actors behave, it cannot be used to explain why and how coordination failure in ship handling occurs. However, the
Identifying Problems through Gaming (Richards and Graham 1977)

Interactive Planning
Robustness analysis
Soft System Methodology (SSM)
Strategic assumption surfacing and testing
Strategic Choice Approach (SCA)
Strategic Options Development and Analysis (SODA)

Problem Structuring Methods

Hard / Decision Context PSMs

Soft / System Context PSMs

The Theory of Games (von Neumann and Morgenstern 1944)

Prisoner’s Dilemma (Flood and Drescher 1950)

Equilibrium (Nash 1950)

Games and Decisions (Luce and Raiffa 1957)

Strategy of Conflict (Schelling 1960)

Exchange Modelling (Coleman 1972)

Networks of Corporate Power (Stokman et al. 1985)

Theory of Moves (Brams 1994)

Theoretical Refinements (Fang et al. 2003)

Drama Theory (Bennett et al. 1992)

Conflict Analysis (Fraser and Hipel 1984)

Hypergame Analysis (Bennet 1977)

Metagame Analysis (Howard 1971)

Analysis of Options (Ackoff et al. 1969)

Graph Model for Conflict Resolution (Fang et al. 1993)

Soft N-Person Games (Bennett 1998)

Confrontation Analysis (Bennett 1999)

Theory of N-Person Games (Rapoport 1970)

Bayesian Games (Harsanyi, 1967)

Theory of Moves (Brams 1994)

Fig. 16. Inventory of PSMs based on Cunningham et al. [2015], figure 1, p.7
construction of outcomes with the use of options is useful, because the outcomes for the different players of the departure order game are not known.

**METAGAMES/CONFLICT ANALYSIS**

Metagame analysis is a game theoretic model built with the analysis of options method [Lei & Thissen, 2009]. To be precise, the analysis of options method is extended with a theory on actor behaviour. Conflict analysis meanwhile adds to metagames with algorithms that help code different outcomes, allowing for an easier analysis of the game, as well as different possible solution concepts [Yin, Hipel, & Lind, 1988]. The solution concepts entail the consideration of the stability of a certain outcome if the game is played more than once (i.e. ‘can any player improve unilaterally in this specific outcome by changing his actions? If so the outcome is likely not stable’).

A metagame/conflict analysis approach seems to fit well with the problem situation. A theory on actor behaviour is incorporated in the methods and the outcomes can be constructed through conceiving of the options of the players (lowering the information demand). Moreover, the solution concepts and coding algorithms can potentially be used to simplify the analysis.

**HYPERTABLES ANALYSIS**

Hypergame analysis is an extension to the Game Theory model that loosens the assumption of players having full information about the game they play [Bennett, 1977]. By formulating ‘perceived’ games and subsequently solving the problem from these perspectives, hypergames can show how different perceptions of actors can determine the outcome of a problem situation [Lei & Thissen, 2009]. For example, an application of a hypergame on a case study in the oil shipping business shows how outcomes are influenced if players perceive the available actions the other player wrongly [Giesen & Bennett, 1979]. Another applications analyses how a negotiation is played out if a player misjudges that there is another bidder [Bennett, 1980]. Differences in perceptions off preferences on outcomes can also be dealt with by the framework, as is shown in [Bennett, Huxham, & Dando, 1981].

The hypergame method provides an elegant solution to game theory for the fact that parties don’t always have a full understanding of the game they play. In hypergames the players of the game perceive the game structurally different. This seems to work well with games that are new to the players (e.g. one-off negotiation) or in which there is conflict between parties. Parties involved in coordinating the departure of a ship are doing that on a regular basis in cooperation with each other. It therefor does not seem likely that any of the departure order game’s players perceives the game structurally different from the other players.

**DRAMA THEORY**

“Drama theory evolved from metagames and takes the concept of metagames further, because irrational behaviour—that is, preference changes and option changes—are allowed. The preference changes are induced by the emotions of actors. The objective of drama theory is to come to a resolution of a problem situation through allowed preference and option changes.” [Lei & Thissen, 2009]

This method does not fit with the main research question. The role of emotion in the coordination process of a departure of a ship is unclear. Hence the usability of drama theory is questionable.
Brams [1993] adds a ‘dynamic dimension’ to classical game theory by enabling players to look ahead several steps, before making a move in a game. By doing so the framework shows that different equilibrium outcomes can be achieved for games compared to the same game in classical game theory. The possibility for players to only have incomplete information is also showed by Brams.

The extension to classic game theory that the Theory of Moves offers is interesting. Using elements of it could lead to more realistic assumptions on actor behaviour. However, this dynamic having players look ahead several moves in a game will be difficult to incorporate if the number of steps becomes bigger. The departure order game meanwhile involves seven parties, each with at least one decision (step). Using this method thus does not seem viable, considering the timeframe of this document.

---

**CONCLUSION**

Some of the methods discussed have a very specific area of applications. A metagame/conflict analysis approach however seems to fit well with the problem situation.

### 3.4 CONCEPTUAL DESIGN

#### 3.4.1 FRAMEWORK THAT WILL BE USED

Metagames have six elements that need to be specified to form a game. **Players** are the parties that have actions within the situation that is described. These players have choices they can make, called **actions**. A game can be sequential or simultaneous. If they are sequential the player take turns in carrying out their actions. The **order of play** describes that sequence. **Outcomes** are the result of the strategy (set of actions) that players take. Outcomes can consist of many different things; a delay of a ship X or a profit Y. **Payoffs** meanwhile are the utility that each player realizes for a particular outcome. In GSMs the assumption is that players choices are driven by the payoffs they expect to achieve. Players in a game do not always know all these elements. **Information** entails the assumption on what elements are known to players.

In a metagame analysis, the outcomes are constructed with the options of the players. To answer the main research question (see paragraph 2.7.2.) the outcomes must consist of; **the delay that players X experiences [hour]**, **the delay that player X causes [hour]** and **cost of delay that player X experiences [€]**. It is necessary to use a simulation model to calculate the value of the outcomes as the number of outcomes and variables is too large to calculate by hand. Chapter 5 describes that simulation model.

Once the elements above are specified for the departure order process of a container process, a single game is created. However, the players play that game several times a day, with different shipping companies, with different ships, with different schedules and different delay costs. The outcomes of one game have consequences for the next. The payoffs of the choice of parties are dependent on the outcome of the previous game. For example, if a tugboat is delayed for some reason in a game, the payoffs of the players in the next game involved with that tugboat can be affected. Therefore the outcomes of these games, the payoffs of parties and the choices they make are dynamic. Paragraph 4.2 explains how to deal with that.

#### 3.4.2 USE OF THE FRAMEWORK

The main goal of the game is to provide insight into patterns of behaviour of players. The behaviour has to correspond to reality. The hypothesis is that that can be done by getting the values (in this case expressed in time and money) and assumption about actors right,
because the players are driven by their values in the game. This has to be checked though (see chapter 7 on validation). If that is achieved, then the behaviour of players in the games can be explained, providing insight into why and how coordination fails. The approach is similar to an exploratory modelling approach; you know that the model is never exactly going to predict what is going to happen, what is of interest are the emergent patterns and type of interactions within the model. Further elaborating: the value of the approach is not that the average delay based on the model is 30 minutes because of the interactions between the shipping agent and the tugboat company. Rather; because shipping agents think they can benefit from ordering a departure too soon and tugboats cannot refuse to wait, delays in the ship handling chain are reinforced. Subsequently; if measure X is put into place the incentives of the shipping agent are changed in such a way that he does not order too soon, resulting in a significant decrease in the average delays compared to the delays shown in the current situation.

3.5 RELATED WORK

With the research approach clear, a comparison can be made with overlapping literature. Contrasting the thesis with related publications helps to understand in what ways this thesis is contributing to the research field. The approach ties into three fields of literature, problem structuring method literature, applied game theory literature and supply chain management literature. The paragraph should make clear that both the approach and application area are novel.

3.5.1 APPLIED GAME THEORY

Given the origin of GSM, the field of applied game theory is related. At the same time it is also very different, in its goal, end result, form and perspective on problems. Often literature addresses optimisations problems, for a single profit function or actor. Thereby the perspective is one that is mono-attribute and mono-objective. In contrast, GSM, and this thesis as well, holds a multi-attribute and multi-objective perspective. Win-win situations are sought. The applied game theoretic literature is often abstract and difficult to follow for those without mathematical expertise. For example see [Lozano, 2013] and [Reyes, 2005].

3.5.2 APPLIED TO SUPPLY CHAINS

Game theoretic approaches to supply chain management are similar to the applied mathematics literature in the sense that often the objective is to optimise a profit function for a single supplier or retailer [Cachon, 2003; Cachon & Netessine, 2004; Chongchao, Gang, Song, & Xianjia, 2006; Hennet & Arda, 2008].

Two instances of a PSM approach to supply chain management have been found during a literature research. One text describes an application of Soft System Methodology, which is a PSM focussing on the system context, while GSMs focus on the decision context of a problem situation [Smith et al., 2002]. The other article explains the use of drama theory analysis on supply chain collaboration [Simatupang & Sridharan, 2011]. The relation with drama theory has been explained in paragraph 3.3.2.

3.5.3 APPLIED TO THE SHIP HANDLING

While there are different approaches to problems, there are also differences in problems. A review article on supply chain coordination from Arshinder et al. [2011] provides several characteristics to distinguish the type of supply chain problem under consideration.

The interface of the supply chain refers to the structures of the parties in the supply chain. In other words; whether the supply chain consists of a supplier and a manufacturer,
a manufacturer and a retailer, one manufacturer and several retailers, etc. In that regard
the ship handling chain is a supply chain consisting of multi-buyers, multi-suppliers, though
it might be better to coin it differently. The reason for that is that the ship handling chain
does not consist of a single supply chain; rather it is a constellation of several pieces of
supply chains, coincidently sharing and competing for port resources. Due to that interface
there is also no central hierarchy in the ship handling chain. The review from Arshinder et
al. [2011] does not show literature that researches a supply chain with that kind of
interface.

The type of sector of the supply chain is another variable which allows positioning
of this research. The game theoretic approaches to supply chain management do not seem
to address supply chains in the maritime sector.
4. DEPARTURE ORDER GAME

This chapter will specify the elements of the GSM framework for the departure order game. To be able to do that in a meaningful way, first some strategic hypothesis are formulated to make the goal of the game more clear, then the departure process will be described in more detail and the boundaries of the game will be presented. The paragraphs thereafter each describe one of the game elements described in paragraph 3.4. Lastly, implications for the simulation model will be set out.

The relation between the game modelled in this chapter, and the simulation model discussed in the next chapter is unorthodox and requires some clarification. This chapter will specify the six elements of the GSM framework, namely players, order of play, information, actions, outcomes and payoffs. The outcomes are specified through two mathematical (spreadsheet) models, one to calculate delay and the other to calculate costs. To generate a large number of these outcomes, a simulation model is needed. This simulation model is discussed in chapter 5. It integrates the two mathematical models in its own model language. The other elements of the game are not changed from chapter 4 to chapter 5. Subsequently, the simulation model is verified. The sixth chapter analyses the outcomes of the simulation model and also discusses the sensitivity of that model. The validity of the results from that analysis are discussed in chapter 7. Figure 17 visualises the relationship between the chapters.

Figure 17: Relation between chapter 4, 5, 6 and 7
4.1 GOAL OF THE GAME

The goal of the model needs to be specified further than is previously done in paragraph 2.8 and 3.4 to argue for the modelling choices made throughout this chapter. This can be done with the formulation of strategic hypotheses on how players act and by listing the interventions that will be researched. Some attention will be given to the intervention strategy as well.

4.1.1 STRATEGIC HYPOTHESES

The hypotheses stated below formulate the behaviour that each player will show, if driven by time and cost incentives. They are based on the interviews with experts of several chain parties. Moreover, if all hypotheses are supported they provide an explanation for unreliable ETDs and thereby delays in ship handling. Which in turn answers the main research question, stated in paragraph 2.7.2. The less-obvious hypotheses will be explained.

- **Strategic hypothesis 1:** Container terminals have an incentive (expressed in time and money) to communicate an expected end-of-ops-time that is a low estimate of the end-of-ops-time they actually perceive to be true (i.e. communicate an unreliable ETD).

- **Strategic hypothesis 2:** Shipping companies have an incentive (expressed in time and money) to communicate an estimate time of departure that is lower than the ETD they actually perceive to be true (i.e. communicate an unreliable ETD).

- **Strategic hypothesis 3:** Shipping companies with smaller ships don’t have an incentive (expressed in time and money) to communicate an estimated time of departure that is lower than the ETD they actually perceive to be true (i.e. communicate an unreliable ETD).

  A difference in the incentives of shipping companies is expected because of two reasons. The first one is that figure 8 in paragraph 2.3.3 shows that larger containership are delayed more often than their part in all containership departures might explain. Moreover, experts at the Port Authority, relayed complaints from smaller shipping companies to me about the ‘expensive’ nautical service providers. This led to the idea that there might be a ship size at which the profit of ordering a departure too early is not enough to cover the penalties other parties charge the shipping company for caused delay.

- **Strategic hypothesis 4:** Other parties experience damage from unreliable departure orders, but their financial damages are relatively low. The incentive to counteract unreliable departure orders is thereby existent, but small.

  Firstly, this conclusion is expected because none of the experts interviewed put forward the incentives of these other parties as an explanation for delay in ship handling. Another reason is that these parties are more active in participating in various kinds of initiatives to change the ship handling process as a whole (e.g. the Pronto project). This suggests that these parties are not able or willing to act according to direct cost and delay incentives in the current process.

- **Strategic hypothesis 5:** These incentives lead to unreliable departure orders, which result in Pareto optimal outcomes. As shown by paragraph 2.3, an unreliable ETD is something that is a common occurrence in the daily business of ship handling. This means that this outcome is somewhat stable, it does not solve itself. If the unreliability can be partly explained by the incentives of players, it would make sense that reaching a different outcome is not beneficial for some players. If the outcome is Pareto optimal, that would explain this stability.
4.1.2 INTERVENTIONS TO RESEARCH
The model analysis should result in recommendations for improving the reliability of ETDs. There are three ways to intervene in the ship handling system that the research method is suited for to explore further.

The first way is intervention with moves in the game. To make that more clear; if strategic hypotheses 1 and 2 are true, what can other parties do within the model to ‘make their lives easier?’ It could be that these parties are not using these options due to the relation they have with a shipping company and terminal. If strategic hypothesis 5 is supported, interventions with moves in the game would lead to situations in which at least one party is worse off. That would complicate interventions such as these.

Assuming that the strategic hypotheses are supported by the result of the simulation model, some thoughts can be given to value sharing interventions, to remove or add incentives. One example would be to increase the waiting costs that nautical service providers charge, or investing in over-capacity of nautical service providers. The exact effects of these interventions are beyond the scope of the thesis. However, because the delay cost per player are part of the model, it provides an excellent opportunity to point out what value can be created for each party by changing an incentive.

The last interventions that will be considered are Interventions on the information element of the game. Coordination problems are often addressed by sharing information between parties (e.g. the Pronto project). Projects that aim to achieve shared information on all kinds of aspects related to ship handling are however met with some resistance. Manually updating the constantly changing information with all involved parties is too resource constraining. At the same time, it can be technically difficult and expensive to couple different types of computer systems and software the parties use. Given this resistance, it would be interesting to investigate where (between which players) information sharing would have the biggest effect (in reducing delays). To answer that question the model needs to be able to show situations in which information availability is increased piecewise. The challenge is how to model situations in which information is partly shared. Paragraph 8.3 elaborates on that.

4.1.3 INTERVENTION STRATEGY
In GSMS a distinction is made between cooperative and non-cooperative games. How interventions are done depends on the type of game. This paragraph briefly discusses what type of game will be specified.

A game in which players can make binding commitments is called a cooperative game [Rasmusen, 2001]. In such games you assume that there are frameworks for effective collective action. These are games in which a group of player may enforce cooperative behaviour. The game is then played between coalitions, instead of between players.

If players cannot enforce cooperative behaviour, it is a non-cooperative game. To clarify, while players can cooperate in these games, any cooperation must be self-enforcing. One of the most important premises to that departure order game is that coordination fails because individual players choose to do so. The departure order game is therefore best described as a non-cooperative game. This implies that the game must be remedied step by step or actor by actor (instead of coalition by coalition).

4.2 BOUNDARY CONDITIONS
Figure 18 shows the departure order game coordination process for the involved parties. This figure is based on an earlier made process diagram from the Port Authority. A so called swimming lane approach has been used to indicate which party takes part in which part of the process [Grund, 2014]. Interestingly enough, the original diagram did not include the
coordination of the shipping company and terminal. The process started when the shipping
agent send out a departure request. Considering that chapter 2 showed that cargo
operations of container terminals are not always finished while the departure order has
been made, it is clear that the coordination of the terminal and shipping company needs to
be included.

In the diagram every arrow that switches ‘lanes’, indicates a coordination moment.
In game structuring terms all of these moments could at first glance be considered a 2-
player game. At the first horizontal arrow, for example, the terminal communicates the
time of completion of its cargo operations to the shipping company, which subsequently
interprets it. The terminal has a choice in when to communicate, how to communicate and
what to communicate. Its choice has an effect on the outcome of that game and
subsequently the payoff for the terminal and shipping company. However, the outcome
of the game is not completely determined by the coordination between the terminal and
shipping company. Moreover, it is likely that the terminal bases its decision in what to
communicate to the shipping company on the expected reaction of the pilots and tugboat
companies later on in the process. There are dependencies with other coordination
moments throughout the diagram. Therefor it makes more sense to consider all these 2-
player games as a coherent whole: the departure order game.

This chapter will describe and model the coordination within the departure order
game, the internal business processes of the individual parties are not modelled. The
previous chapter explained that the departure order game is played several times a day and
that the outcomes of one game have consequences for the next. One example of a
consequence of a game for the next could be that the nautical service providers are
delayed, leaving them with less capacity in the next game. Yet this paragraph will model a
single game, to limit the complexity and keeping the timeframe of the research
manageable. Dynamically linking two or more departure order games is difficult for a
number of reasons.

The first reason is that the effect that a certain outcome (for example delay
tugboats) could have on another departure order game is not directly felt in the next game
because they travel through the ship handling chain. To elaborate, the pilot association
tries to couple an outgoing trip to a subsequent incoming or shifting trip. In this way,
resources are spent more optimal. So, if a pilot is delayed in the departure order game, its
delay is not necessarily felt by another outgoing ship, but rather an incoming ship (which
could in turn delay an outgoing ship, etc.). Effects are thus not transferred 1-to-1 from
departure game to departure game. So, estimating these effect requires the modelling of
other ship handling process steps and likely also internal business processes of players. One
would have to account for the relative distance between two ships, lack or slack in schedule
of players, schedules of nautical service providers and a plethora of other factors.
Essentially, an effort would have to be made to model the entire ship handling process in
greater detail.

Secondly, dynamically linking games is complex because the players of one game
are not the same as in the next. For example, from one game to the next the ship could be
from another shipping company, which is laying at a different terminal, has a contract with
a different shipping agent and does not get tugboat assistance from the same company or
the same tugboat, etc. It would become very difficult to account the cost and delay for all
these parties.

Instead of dynamically linking two departure order games the ‘supply chain effects’
could be reflected in input variables or scenarios in which the game is played. Different
possible inputs then account for possible influences that previous games may have had.
Instead of going through the effort of estimating the effect of a delay for a tugboat in one
game to the next, it is for example easier to just assume there is low tugboat capacity at the
start of a game.
The boundaries of the game can be made more explicit by considering the game as a system with inputs, outputs and external influences. Figure 19 shows a system diagram that visualises these elements. The diagram clearly shows three sub-systems (blue outlined boxes) that have to coordinate their actions to make a departure happen.

Figure 18: Process diagram of coordination process for the departure of a ship
4.3 PLAYERS

The role of the different parties in ship handling is described in paragraph 2.5.1. That brief description focussed on the ship handling process in general and ignored any pluralism between parties. In this paragraph the role that players specifically have in the departure order game will be explained. Next, differences in the size and type of the resources of a player will be discussed, because they could affect the outcome of the game. Relations (contractual) with other parties cannot be ignored either, because they influence the outcomes in a similar way.

4.3.1 TERMINAL

Ships depart from the quay belonging to a container terminal. The involvement (not similar to influence) of a container terminal in the game is quite limited; it only needs to communicate the end of ops time to the shipping company. Container shipping liners usually have a Service Level Agreement (SLA) with the terminal, relating to the berth productivity and specifying penalties for waiting times. The implication of that is that terminals have incentives to handle a ship as quickly as possible (generally speaking). Since these SLA’s are negotiable, the height of the incentives are unknown. What can be reasonably assumed is that the bigger a ship is, the higher its delay cost, thus the higher the incentives are to handle it.

4.3.2 SHIPPING COMPANY

The shipping company in this game is represented by the captain of the ship. He decides when the ship is ready to depart and how many tugboats to use (among else). The captain’s role in the game is to interpret the end of cargo operations time he receives from the...
terminal and to communicate a desired departure time to the shipping agent. Commonly, once the cargo operations are finished both the captain and terminal want the ship to leave the berth as soon as possible.

Shipping companies also have contracts with specific tugboat companies. A shipping company could represent a very substantial part of the income of a tugboat company. As a consequence loyalty to the customer (i.e. shipping company) could be shown in the payoffs of tugboat companies for their bigger clients.

4.3.3 SHIPPING AGENT

Shipping agents are intermediaries for shipping companies between them and many other companies in the port. During the departure game their role consists of setting up a departure order (includes; the time at which the pilot, tugs and boatmen are requested and requested departure time) and communicating this to the Port Authority.

Shipping agents can play that role for a single client or multiple. The formal chart in paragraph 2.6 showed that agencies can be owned by (or have a sister company that is) a shipping company. One would suspect that the incentives of an agency that is owned by a shipping company are better aligned with that shipping company, but according to representatives from Shell and Maersk Line that is not the case (B. van Scherpenzeel, personal communication, 13, March, 2015). Different sister companies often have to make their own business case. Also surprising is that agencies have no direct financial incentives included in their contracts with shipping companies to minimise the port stay time. Possible explanations are that delays are difficult to define, monitor, and account to the causer.

One choice about the type of agency that could influence the outcomes of the game is regarding the number of port calls an agency does in the Port of Rotterdam. Should an agency handle enough calls, a ship could potentially experience delays caused by the actions of an agent caused earlier. However, this hypothesis is solely based on self-gained insight. To maintain computational feasibility, this variable was therefor dropped from the model.

4.3.4 PORT AUTHORITY

In this game the Port Authority is represented by the harbour master division. The Harbour master division is a department within the Port Authority that has public competences. The Harbour Master is the appointed (by national government and municipality of Rotterdam) authority with regards to safeguarding a safe and nautical efficient handling of shipping. The Harbour Master in that respect has three roles [Grund, 2014];

Authority: The Harbour Master assesses every planned trip of a ship from the perspective of safety for the shipping traffic as a whole. The Harbour Master has the competence to refuse a certain time of departure of a planned trip if the nautical safety is threatened. In the assessment among else the availability of berths, hydrological and meteorological circumstances, quall clearance and availability of nautical service providers is considered. In the game only the availability of the nautical service providers and the capacity of waterways is considered. Incorporating the influence of other factors on whether the Harbour Master refuses a certain trip would unnecessarily complicate the game.

Manager: The Harbour Master manages the nautical infrastructure and the scarce capacity of the waterways. More specifically this means that the Harbour Master decides, at points where capacity is limited, on the order in which ships can pass each other. The main principle is ‘first come, first serve’ but additional criteria are used if the total flow of the shipping traffic can be improved and the accessibility of the Port has to be guaranteed.

Facilitator: Nautical Service Providers are responsible for their own planning of resources. The Harbour Master sets out conditions which these plans should meet (e.g.
time frame of the departure order) and checks whether the Nautical Service Providers have confirmed their response for every planned trip of a ship. If these requirements are not met, the Harbour Master does not give clearance for the trip.

Regarding the relation with other players; differences in the type of ship and shipping company are reflected in the payoffs of certain outcomes of the Harbour Master. A delay for a shipping company that can be considered a big client to the Port Authority (big ship or frequent visitor) is likely to be experienced as worse than a delay for a normal client.

4.3.5 TUGBOAT COMPANIES
There are four different tugboat companies in the Port of Rotterdam. The companies provide their services to their own clients (shipping companies). In the departure order game they coordinate with the Port Authority at the time when tugboats can possibly arrive at a quay. Also part of the game is the response of the tugboat companies to the departure order (as the time at which tugboats could arrive are not necessarily the time at which they arrive).

Some clients may be bigger than others. As explained earlier, this could affect how willing tugboats are to cause a delay for a shipping company. There are also differences between the tugboat companies themselves. They use different type of tugboats and they have different capacity for example. These last differences are not considered in the game though.

4.3.6 PILOTS
Pilots provide navigational and advisory services to a captain on board of a ship in and near the Port area. The independent professionals are organised in the Pilot Association, which takes care of the planning process. The Association is monitored by the ACM (Authority for Consumers & Markets), because of the monopoly they have on providing pilot services. The ACM also sets fixed tariffs, taking into account the type of ship and kind of trip. The pilots themselves are specialised towards sailing a certain type of vessel, in a specific regions of the Port. Thus not every pilot can depart with a containership of more than 300 meters long from a specific quay. Though, this level of detail is beyond the scope of the model.

4.3.7 BOATMEN
Boatmen provide assistance in mooring and unmooring of vessels. More specifically, they handle the lashings of a ship. The boatmen provide their service to all ships in the Port. There is only a single boatmen company operative in the Port of Rotterdam, but it is not a legally assigned monopoly.

Both the data on delays and the interviews that have been conducted with different parties currently point out that the Boatmen are practically never late. Apparently, they have the capacity and flexibility to respond to every order. Because the number of variables in the model has become quite large, the boatmen will be in the game as a pseudo player, giving them only the option of responding to actions on time (leaving them out entirely might leave the game unrecognisable for parties). However, you could question if the boatmen are not operating at too high costs and too much capacity if they can respond to every order and somehow be able to mitigate the delay costs. Unfortunately, the model will not provide insight in this.

4.4 ORDER OF PLAY
In the game there is a specific order in which players act. That order is described by the process diagram (see figure 18). While not technically a player, the game starts with the generation of input variables. This input variables include the size of the ship, the actual
end of ops time for the terminal, the type of players that are part of the game, their contractual relationships and possible consequences from previous games. The resulting order of play is the following:


4.5 ACTIONS AND INFORMATION

This paragraph will describe the actions of every player in the order of play. Since the actions that players have are in essence coordinating and communicating moves, the element of information is inherently bound to the actions. The first part will therefor describe the assumptions on what elements of the game are known to the players. Secondly, the setup of the game is described, explaining the possible input scenarios. Then the actions that result in a departure order are depicted. Finally, the possible responses of the NSP are shown.

4.5.1 WHO KNOWS WHAT, WHEN?

In GSMs information describes the assumptions on what elements are known to players. This paragraph will define the information availability of the game in the same way Rasmusen [2001] does. In that respect, the information in the departure order game is imperfect, incomplete, asymmetric and certain.

In a game of complete information, nature does not move first, or her initial move is observed by every player. To clarify; a move of nature can be understood as a change in the state of the world that the game is played in. Nature moves first in the departure order game (see previous paragraph) and is unobservable for most players. In other words, players do not know exactly what game they are playing (e.g., a tugboat company cannot observe the time at which the cargo operations are finished before making a decision). Hence information is incomplete.

Perfect information refers to knowing the moves that are done by other players. In game theoretic terms; “each information set is a singleton” [Rasmusen, 2001]. A player with a singleton information set implies that this player knows exactly where he is in the game (decision) tree. This can only be the case if no moves are simultaneous, and all players observe nature’s moves. Considering that the actions in this game are primarily done through communicating over distance, there is no way of knowing what the other player has done for certain, until the player himself has acted. Information is imperfect.

Symmetric information means that no player has information different from other players when he moves, or at the end of the game. This obviously is not the case. A terminal for example has knowledge about the time at which the cargo operations are finished, a tugboat company has knowledge about its capacity. Information is asymmetric in that sense.

A game is certain if nature does not move after any player moves. The boundaries of the game are set in such a way that internal business routines (such as capacity management), hydro/meteo characteristics and other factors are not included in the game. In reality these factors can influence the departure of the ship, but are left out of the model to limit the complexity. As a result the game is certain. The consequence that this choice has for the expressive power of the game is something that is reflected upon in chapter 7.

To answer the question of ‘who knows what, when?’ every description of an action in the next paragraph will end with a small summary (shaded in grey for readability purposes) of the information available to the respective player.
4.5.2 SCENARIOS
The first paragraph of this chapter addressed the difficulty of dynamically linking two departure order games and argued that input variables to the game could serve as a way to take into account that outcomes of one game have influence in others. Meanwhile, paragraph 4.3 explained that there are differences in the size and type of the resources and relations of players. These differences could affect the outcome of the game as well. This paragraph will depict the input variables that will be used to account for these differences. In a way a sort of scenarios are made.

SUPPLY CHAIN EFFECTS
For the departure of a ship, resources from the nautical service providers are needed. If these resources are unavailable, due to earlier games, this will lead to different actions and outcomes. Hence, two variables are included to describe whether a NSP is available for the ship (the boatmen are a pseudo player, therefor always available).

During times in which NSPs cannot meet orders within two hours anymore, they can communicate (through the Harbour Coordination Centre of the Port Authority) a capacity arrangement. When in effect, the capacity arrangement extends the timeframe of orders (e.g. a tugboat capacity arrangement requires all tugboat orders to be send in three hours in advance, allowing more time to react on the orders. Scenarios can be made where the capacity arrangement is in effect or not. Note that NSPs can be unavailable while there is no capacity arrangement in effect (e.g. when there is a delay).

Busy times can also lead to crowded waterways. As explained earlier, the Port Authority manages the order in which ships can pass each other at points where the capacity of the waterway is limited. To reflect this constraint a variable could mark the games in which there is scarcity of waterway capacity.

Similar to the capacity of waterways the cargo operations of a terminal are beyond the scope of this research to investigate or model in depth. Nevertheless, the time the cargo operations at the terminal are finished is a necessary variable to include in the scenario. This is because players coordinate their actions based on their estimation of what that time is. To prevent modelling the cargo operations in all its complexity, the actual end of operations time will be determined as a constant during the setup of the game.

DIFFERENCES IN PLAYERS
The description of the players in the previous paragraph hinted a few times that the size of the ship under consideration is likely an important determinant for how players act. The bigger a ship is, the bigger part of income it could represent for companies. Ships can be divided into different size classes, namely: Feeder (TEU 0-3000), Panamax (TEU 3001-5100) Post Panamax (TEU: 5101-10000), New Panamax (TEU: 10000 – 14500) and Ultra Large Container Vessel (14,501 and higher TEU). Taking all classes into account would quickly lead to a too large number of possible outcomes to effectively analyse. Therefor only two ship sizes are accounted for; the largest and the smallest. For the input scenarios a size roughly at the midpoint of these classes will be chosen. Should players coordinate differently for a small and a large ship this could lead to recommendations of investigating this more in depth and to recommendations on which business routines to adjust accordingly should a large or small ship be at play.

Differences in other players and their resources that have previously been named are not considered as it is not clear how these differences will affect the coordination between players and how to express them within the game structuring framework. Table 2 meanwhile summarises the variables that make up the input scenarios and the values that these variables can attain.
4.5.3 STEPS IN DEPARTURE ORDER PROCESS
The following two paragraph describe the actions that the players have at their disposal. See appendix C, for a more extensive argument of why these actions are feasible for the players.

THE TERMINAL
The terminal has to communicate the end of operation time (EoOT) to the shipping company, so that they can make arrangements to clear the berth. Roughly said, the end of ops time is the time at which all containers are loaded or offloaded to a ship. Given the fact that terminals handle several hundred of ships a year and the fact that they want to optimise their berth utilisation, it is reasonable to assume that they can estimate to some degree of accuracy the actual end of operations time (AEoOT).

Knowing the best possible estimation of the end of ops time does not necessarily mean that terminals will communicate that. What time they communicate influences, but not fully determines, the time that the berth will be cleared by the ship. Hence, in the departure order game the choice terminals are faced with consist of communicating a low, best of high estimate of the end of operations time. On the basis of this decision the terminal has a perception of when the shipping company will order the NSP and when the ship can depart.

Possible actions:
- Communicate low estimate of end of operations time
- Communicate best estimate of end of operations time
- Communicate high estimate of end of operations time

Information:
Known: Actual end of operations time
Unknown: Desired arrival time NSP

SHIPPING COMPANY
Having received an end of operations time, the shipping company now has to account for the time that is needed to prepare the departure of the ship. It takes the nautical service providers some time to prepare a departure. This preparation includes a pilot coming on board, discussing the unmooring manoeuvre, boatmen removing the lashings, coupling the tugboats and other things. Meanwhile, the actual departure time is the AEoOT plus the time needed for preparation. If the nautical service providers are present before the AEoOT the departure time moves closer to the AEoOT. Important to remember is that the shipping company only has a perceived end of operations time that might differ from the actual end of operations time (depending on what the terminal communicates).

Given the above, the shipping company has to communicate a desired arrival time of nautical service providers to the agent, to let him make a departure request. The choice that shipping companies are faced with consist of communicating a desired arrival time of nautical service providers relative to the perceived EoOT. On the basis of this decision the

<table>
<thead>
<tr>
<th>Table 1: Input scenario variables</th>
<th>Attainable values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tugboats available</td>
<td>Yes, No</td>
</tr>
<tr>
<td>Pilots available</td>
<td>Yes, No</td>
</tr>
<tr>
<td>Capacity arrangement</td>
<td>Yes, No</td>
</tr>
<tr>
<td>Scarce capacity waterway</td>
<td>Yes, No</td>
</tr>
<tr>
<td>Ship size (TEU)</td>
<td>1500, 16000</td>
</tr>
</tbody>
</table>
The shipping company has an expectation of when NSP will arrive and when the ship can depart.

**Possible actions:**
- Communicate desired arrival time of the NSP before EoOT
- Communicate desired arrival time of the NSP at EoOT
- Communicate desired arrival time of the NSP after EoOT

**Information:**
- Unknown: Actual end of operations time
- Known: Perceived end of operations time

---

**SHIPPING AGENT**

Based on the information communicated by the shipping company, a shipping agent sets up a departure request and sends it to the Port Authority. This departure request consists of a desired departure time, the desired arrival time of the NSP and includes information about the ship, its cargo, the number of tugboats required, etc. The scope of the research only includes the departure time. Given that the shipping company is the client of the agent, it seems infeasible that the shipping agent counteracts the choice the shipping company makes (in either direction). Therefore, the shipping agent is modelled as a pseudo player, having only the option to communicate a desired arrival time of the NSP and related ETD that have been received by the shipping company.

**Possible actions:**
- Communicate received desired arrival time of the NSP

**Information:**
- Unknown: Actual end of operations time
- Known: Perceived end of operations time

---

**PORT AUTHORITY**

Having received the departure request from the shipping agent, the Port Authority determines whether the departure order can be carried in a safe manner or if it should delay the departure time. In both cases, the order is communicated to the nautical service providers. As explained in the previous paragraph, in reality a great number of factors are taken into account when assessing the safety of a departure order. However, in this game only the availability of the nautical service providers (whether a capacity arrangement is in effect) and the capacity of the waterways are considered. To clarify, the Port Authority decides on the order in which ships can pass each other, at points where capacity is limited. The main principle is 'first come, first serve' but additional criteria are used if the total flow of the shipping traffic can be improved and the accessibility of the Port has to be guaranteed.

**Possible actions:**
- At requested time
- After requested time

**Information:**
- Unknown: Actual end of operations time
- Known: Desired arrival time of nautical service provider
PILOT
Once the departure request has been received by the Pilot association, they will have to schedule a pilot to act on the order. Depending on the planning of the Pilot association the order has to be confirmed or amended. A feasible pilot on board time has to be communicated to the agent.

Possible actions:
- At requested time
- After requested time

Information:
Unknown: Actual end of operations time
Known: Desired arrival time of nautical service provider

TUGBOAT COMPANY
Once the departure request has been received by the tugboat company, they will have to schedule one or multiple tugs to act on the order. Depending on the planning of the tugboat company the order has to be confirmed or amended. A feasible tugboat at berth time has to be communicated to the agent.

Possible actions:
- At requested time
- After requested time

Information:
Unknown: Actual end of operations time
Known: Desired arrival time of nautical service provider

BOATMEN
Once the departure request has been received by the boatmen, they will have to schedule boatmen to act on the order. Depending on the planning of the boatmen, the order has to be confirmed or amended. A feasible boatmen at berth time has to be communicated to the agent. However since, the boatmen are a pseudo player, they only have the option to confirm the order.

Possible actions:
- At requested time

Information:
Unknown: Actual end of operations time
Known: Desired arrival time of nautical service provider

4.5.4 ACTING ON ORDER
The departure order is now final. This paragraph will discuss the actions the nautical service providers have in response to that departure order.
PILOT
At this point the Pilot association has communicated an expected pilot on board time. The question now is; what degrees of freedom does a pilot have in responding on a departure order? Earlier mentioned interviews show that there can be a difference in what is communicated and how players act. This became apparent from the actions available to for example the terminal or the shipping company. Should a pilot respond to what turns out to be an unreliable ETD, the pilot experiences a delay. This delay could disrupt the schedule of the Pilot association. A pilot could choose to try to prevent that from happening by reacting to the departure order. When confronted with the question whether this option would be conceivable, Interviewees from the Pilots denied, saying the Pilot Law obligates pilots to respond on time. Indeed, article 15 of the Pilot Law (‘Loodsenwet’) states that pilots are obligated to service ships timely and non-discriminatory. Not abiding to this could result in a complaint at the disciplinary board, which can issue a warning, a fine (max €2250), a suspension or limiting of a pilot’s authority. The fact that the law is quite specific about disciplinary action for not acting timely actually makes the action very conceivable (disregarding how undesirable it would be for a pilot). Should the pilot decide to not respond on time, his perceived ETD is adjusted accordingly.

Possible actions:
- Respond on order time
- Respond later

Information:
Unknown: Actual end of operations time
Known: Desired arrival time of nautical service provider
Decision: Response time Pilots

TUGBOAT COMPANY
At this point the tugboat has communicated an expected tugboat at berth time. However, there can still be a difference in what is communicated and how players act. This is true for the Nautical Service Providers, as well as the other players. A tugboat still has the choice (disregarding at the moment how desirable it would be) to respond on the order on time or later. Should the tugboat decide to not respond on time, his perceived ETD is adjusted accordingly.

Possible actions:
- Respond on order time
- Respond later

Information:
Unknown: Actual end of operations time
Known: Desired arrival time of nautical service provider
Decision: Response time tugboats

BOATMEN
As said before, the boatmen will be a pseudo player in the game. Only one response to a departure order is available to them.

Possible actions:
- Respond on order time
Information:
Unknown: Actual end of operations time
Known: Desired arrival time of nautical service provider
Decision: Response time boatmen

4.6 OUTCOMES
The conceivable actions that players have are now made clear. If all players act, a departure will be the result. Paragraph 4.6.1 and 4.6.2 will discuss how the actions are converted into outcomes, in terms of delay and cost respectively. The paragraph thereafter explains how to deal with the fact that these outcomes are not all realistic.

4.6.1 DELAY
Calculating outcomes requires the quantification of the effects of the actions. Table 2 shows the players and their actions schematically. The first row shows that the game starts with selecting an input scenario, as discussed in paragraph 4.5.2. There are 32 possible combinations of input scenarios and 288 possible combinations of actions. To limit the number of possible outcomes to a manageable size, the effects of the actions will be specified on a discrete time scale. Namely, the effects of the actions available to a player differ from each other with increments of 30 minutes. For example the terminal has the possibility to communicate an EoOT that is 30 minutes lower, the same or 30 minutes higher than the EoOT the terminal perceives. In reality players have a continuous time scale of actions to their disposal. Chapter 6 tests the sensitivity of the outcomes through adjusting the chosen time scale. To investigate the strategic hypotheses the effects of actions on the delay that the individual players experience needs to be specified. This is complicated by the fact that the effects of the actions are non-linear with respect to the delay players experience and dependent on each other. For example, if the Port Authority sets a later ETD this can influence the delay experienced by a shipping company both positively and negatively, depending on the action of the shipping company. The explanation for this non-linearity is that players do not directly influence the ATD with their actions, but rather other variables (see previous paragraph), which in turn leads to a departure. The influence of the actions of players on these variables is linear. To calculate the direction and height of a delay the relative position (smaller, equal or higher) between the received and communicated time (and derived perceived departure time), as well as technical limitations (i.e. ship cannot depart before the EoOT) has to be taken into account.

Table 3 shows the times communicated in a single strategy profile (a single branch of the decision tree). The actions taken are printed bold in table 2. This table tells the following story; the starting condition of this game is that the cargo operations end at 15:00. The terminal interprets this AEoOT and decides to communicate the EoOT as 14:30 to the shipping company. It does so under the assumption that the NSP will be ordered for 14:15 (15 minutes before the EoOT, in accordance with business routines agreements between the chain partners). It is assumed that the NSP need 30 minutes to prepare a departure. This communication would speed up the departure process by 15 minutes, because the NSP can prepare the departure. The ETD the terminal perceives is thus 14:45. Meanwhile, the Shipping Company receives an EoOT of 14:30 and decides to communicate the desired arrival time of the NSP of 13:45, also trying to speed up the departure by communicating a too early time. The agent does not divert from the time communicated by the shipping company. Subsequently the departure request is send to the Port Authority. The NSP and the Port Authority schedule the order at the requested time and the NSP responds on the requested order time. The delay matrix (table 4) shows what delay the players experience and have caused in this strategy profile.
The delay matrix is the result of a mathematical (spreadsheet) model, which is able to calculate the delay every player experiences in all strategy profiles. The assumptions and formulas of that model are written down in Appendix E. The most crucial assumptions will be discussed in this paragraph. First of all, the Actual End of Operations Time always is 15:00 in the model. Secondly it takes the NSPs 30 minutes to prepare a departure. The actual departure time is the AEoOT plus the time needed for preparation. If the NSPs are present before the AEoOT the departure time moves closer to the AEoOT. There are procedural agreements between the NSP and shipping agent that the NSPs are usually ordered to be present at the ship 15 minutes before the EoOT. Because it is assumed that a ship does not depart before the EoOT, the maximum time that can be gained by the terminal and shipping company is 15 minutes.

Table 2: Players and their actions

<table>
<thead>
<tr>
<th>Phase</th>
<th>Player</th>
<th>Decision</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario choice</td>
<td>Nature</td>
<td>Which scenario is played</td>
<td>Inputs scenarios</td>
</tr>
<tr>
<td>Order process</td>
<td>Terminal</td>
<td>Communicate estimated end of ops time (EoOT)</td>
<td>Low estimate</td>
</tr>
<tr>
<td></td>
<td>Shipping company</td>
<td>Communicate desired arrival time of NSP</td>
<td>Before EoOT</td>
</tr>
<tr>
<td></td>
<td>Shipping Agent</td>
<td>Communicate desired arrival time of NSP</td>
<td>At EoOT</td>
</tr>
<tr>
<td></td>
<td>Port authority</td>
<td>Determine safety of request</td>
<td>At requested time</td>
</tr>
<tr>
<td></td>
<td>Pilots</td>
<td>Communicate feasible pilot on board time</td>
<td>At requested time</td>
</tr>
<tr>
<td></td>
<td>Tugboat Company</td>
<td>Communicate feasible tugboat at berth time</td>
<td>At requested time</td>
</tr>
<tr>
<td></td>
<td>Boatmen</td>
<td>Communicate feasible boatmen at berth time</td>
<td>At requested time</td>
</tr>
<tr>
<td>Respond to order</td>
<td>Pilot</td>
<td>Respond to departure order</td>
<td>Respond on time</td>
</tr>
<tr>
<td></td>
<td>Tugboat Company</td>
<td>Respond to departure order</td>
<td>Respond on time</td>
</tr>
<tr>
<td></td>
<td>Boatmen</td>
<td>Respond to departure order</td>
<td>Respond on time</td>
</tr>
</tbody>
</table>

Table 3: Single strategy profile of the game

<table>
<thead>
<tr>
<th>Player</th>
<th>Decision</th>
<th>Time communicated</th>
<th>Perceived ETD by player</th>
<th>ETD that is implicitly communicated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario</td>
<td>Actual end of operations time</td>
<td>15:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terminal</td>
<td>Communicate estimated end of ops time (EoOT)</td>
<td>14:30</td>
<td>15:00</td>
<td>14:45</td>
</tr>
<tr>
<td>Shipping company</td>
<td>Communicate desired arrival time of NSP</td>
<td>13:45</td>
<td>14:30</td>
<td>14:15</td>
</tr>
<tr>
<td>Agent</td>
<td>Communicate desired arrival time of NSP</td>
<td>13:45</td>
<td>14:30</td>
<td>14:15</td>
</tr>
<tr>
<td>Port authority</td>
<td>Communicate ETD</td>
<td>13:45</td>
<td>14:15</td>
<td>14:15</td>
</tr>
<tr>
<td>Pilots</td>
<td>Communicate feasible pilot on board time</td>
<td>13:45</td>
<td>14:15</td>
<td>14:15</td>
</tr>
<tr>
<td>Tugboats</td>
<td>Communicate feasible</td>
<td>13:45</td>
<td>14:15</td>
<td>14:15</td>
</tr>
</tbody>
</table>
Table 4: Delay matrix

<table>
<thead>
<tr>
<th></th>
<th>Delay caused by</th>
<th>Terminal</th>
<th>Shipping company</th>
<th>Agent</th>
<th>Port Authority</th>
<th>Pilots</th>
<th>Tugboats</th>
<th>Boatmen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boatmen</td>
<td>Communicate feasible boatmen at berth time</td>
<td>13:45</td>
<td>14:15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pilots</td>
<td>Respond to departure order</td>
<td>13:45</td>
<td>14:15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tugboats</td>
<td>Respond to departure order</td>
<td>13:45</td>
<td>14:15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boatmen</td>
<td>Respond to departure order</td>
<td>13:45</td>
<td>14:15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15:00</td>
<td></td>
</tr>
</tbody>
</table>

4.6.2 COSTS
The delay matrix allows for accounting delays to players. This matrix can be used to calculate the costs resulting from delays. Expressing the effect of actions in terms of cost requires that some assumption are made about what and when cost are experienced. First of all, it is assumed that a delay always lead to costs. These costs are the sum of the cost associated with experienced delay, the cost associated with compensating delay that a player causes for other players and the received compensation costs. The experienced cost can then be calculated with the following formula:

\[ \sum (\text{Delay experienced} \times \text{delay cost per hour} + \text{delay caused for a player} \times \text{chargeable cost for that delay} - \text{delay experienced because of a player} \times \text{chargeable cost for that delay}) \]

The delay cost per hour for a player is assumed to be equal to the opportunity cost of that player (the revenue a player has per hour). Also noteworthy is that in reality not all delay costs are compensated by the causer. Appendix F depicts the calculations behind the different cost parameters and also provides two overview tables with all cost parameters.

4.6.3 THEORY VERSUS REALITY
Now that the influence of the actions can be calculated in terms of delay and cost, the strategic hypotheses can’t be answered just yet. While the actions formulated are feasible, the outcomes they lead to may never happen in reality. Other paths of actions meanwhile
are much more common in reality. The chance of an outcome happening must be taken into account before drawing a conclusion on how a player behaves. Therefore, it could be useful to describe the decision logic of players involved in the departure game. After that, a difference can be made between ‘realistic’ and ‘unrealistic’ outcomes.

Currently, the coordination in the game can be summarised as follows: player 2 has received a departure request from player 1, consisting of a time. Player 2 needs to communicate a time to player 3 and so on. Generally speaking, players have three options; communicate a time to the next player that either is (1) earlier, (2) equal or (3) later than the time received. The decisions are made under the assumption that information is imperfect; players do not know what the other players has done, until they are affected by it. This raises the question; how do players in reality make a choice if they cannot be 100% sure of what the other players has done? Any sensible business would base choices on company policy (inspired by achieved business results from the past), experience of employees, agreements with other parties regarding business routines, and mutual trust, rather than a coin toss. In other words, why would a player consciously choose to communicate a different time than he receives (and not state there is a difference between the two times)? One reason is probably because of (dis)trust he has in the other parties. He could also expect the next party to act on that information in such a way that a desirable outcome is achieved for him. Other reasons such as favours for another party cannot be excluded either. Subsequently, let’s imagine how a decision logic function in a simulation model could look like, given these reasons:

Choice of shipping company = Maximum Expected value of choice

With:

Maximum Expected value of choice = MAX (expected value choice 1,2,3)

Where:

Expected value of choice 1 = Delay associated with strategy profile 1 * chance of strategy profile 1 * utility experienced from delay + Cost associated with strategy profile 1 * chance of strategy profile 1 * utility experienced from costs + ... [All other strategy profiles]

To calculate the expected value of a certain choice, essentially every strategy profile (i.e. branch in the decision tree) has to be assigned a chance of happening. These chances have to be multiplied with a cost and delay for the shipping company. But what are the chances of a player making a certain choice? (i.e. How trustworthy are players in the eyes of others?) and who would know these probabilities? Computationally this method could be challenging as well. Incorporating decision logic is thus difficult. However, there are possibilities of answering the research question without incorporating decision logic in a simulation model.

One suggestion that could be considered is to work the other way around: observe a few scenarios in reality. Code them into the simulation model, calculate the effects in terms of delay and cost, and explain behaviour of players on the basis of this. What you are doing then is looking at a single branch of the decision tree. The simulation model will show a certain delay and cost for each player for that one branch. However part of the challenge lies in diagnosing the current situation, therefore one should model more outcomes than you know to be true. Players are driven by the expected value of a choice, relative to the expected value of other choices. Then this method does not allow the investigation of incentives of players to make a certain choice.

Another approach is to simulate all combinations of choices. That results in a theoretical solution space. The frequency of a certain outcome in the model does not say anything about how often that outcome happens in reality. That translation still has to be done. The first step in that approach would be to look for pockets of outcomes that seem logical for players to strive for. Essentially, these are pockets that have a high expected value compared to other pockets. Then you check the feasibility of them happening in
reality. In that way, both the relative expected value of an outcome is considered, as well as the translation from theoretical outcomes to real outcomes.

The rest of this paragraph will give an example of how that approach works. Figure 20 shows the delays experienced by a terminal, given the decision made by the terminal. Ignoring the difference between theory and reality, one could see that the delay for the terminal on average is lower if the terminal takes decision -0.5 (order early). This supports the strategic hypothesis of ‘terminals have an incentive to coordinate an unreliable ETD’. However, the evidence for that shatters once decision -0.5 is never taken by the terminal (makes hypothesis irrelevant). The hypothesis is also falsified if the situations associated with the peaks shown in the graph (see red circle) in the theoretical solution space have a bigger chance of happening in reality than the area of the graph supporting the hypothesis.

Different experts might know to some extent the ‘modes’ of behaviour of coordination on ship handling. However, one could seriously doubt whether they could assign probabilities to what happens in the port (in terms of choices made by parties) in an unbiased and valid way. They do have a very clear idea on what (almost) never happens. So, if pockets of outcomes can be characterised in terms of decisions made (for example with frequency tables), they can be deemed realistic or not. In that way the strategic hypothesis can potentially be falsified.

4.7 PAYOFFS

The utility that each player realizes for a particular delay and cost is called a payoff. In GSMs the assumption is that players choices are driven by the payoffs they expect to achieve. It is safe to say that players of the departure order game will realise more utility in case that delay and associated cost are lower. That means that to a large extent the behaviour that players are driven to can be derived from the achieved outcomes. Payoffs however are needed when trade-offs need to be made. In other words, whether players are more cost or delay sensitive. The preferences of players can be discovered by confronting the parties in interviews with several outcomes and let them rank the outcomes from most preferred to least preferred. No effort will be made to express utility on a ratio scale, for this report
the payoffs of players will only be discussed in a qualitative manner, whenever it would make a difference (e.g. paragraph 6.2).

4.8 IMPLICATIONS FOR SIMULATION MODEL
The modelling choices that have been made throughout this chapter put requirements on what the simulation needs to be able to do. First and foremost, the aim of the simulation model is to generate the possible outcomes in an automated way. The output of every model run should consist of a delay and cost matrix. Because these outcomes have to be grouped for further analysis, the actions and the input scenario variables chosen per run have to be registered as well. The model thus has to be able to deal with this sizeable amount of data. There is no need of incorporating decision reasoning in the simulation model, game theoretic analysis is done post-run.
5 SIMULATION

The previous chapter sets out the requirements for the simulation model. This paragraph will explain how a simulation model can be made that generates the desired outcomes. The verification of that model will also be discussed.

5.1 SIMULATION TOOL

Netlogo is a simulation package that can be used to generate the outcomes of the game in the desired way. It is a programmable modelling environment that offers the flexibility needed to integrate both mathematical models described in paragraph 4.6 and can output any variable used in the model. Moreover the experimental setup is easy and the results can be written to csv files for later analysis in Excel. Finally, the author’s familiarity with Netlogo makes it a more obvious choice than other simulation packages that could fit the requirements.

5.2 IMPLEMENTATION

The relation between the simulation model and the model specified in chapter 4 is shown in figure 12, at the beginning of the previous chapter. More specifically it shows how the game elements specified in chapter 4 are used in the simulation model. The players, order of play, information and actions correspond one-to-one, while the mathematical models (that are based on the earlier mentioned elements) need to be translated to Netlogo code. This leads to a quite unorthodox use of Netlogo, because key characteristics of the simulation package are not used. This paragraph will therefor briefly discuss how the elements fit into the simulation tool and describe how the mathematical models can be translated to the modelling language.

5.2.1 ELEMENTS OF THE GAME

The simulation model involves the same players as identified in chapter 4. Although in Netlogo language these players are called agents. Only one of each agent type needs to be modelled (i.e. one terminal, one shipping company, etc). Commonly these agents own specific attributes to implement decision logic in the model. Since no decision logic is required in the simulation model, the agents do not own such attributes.

The agents are placed in a ‘simulation world’ that is made out of cells (or patches), called the grid. These patches can also own attributes to facilitate decision logic. Similarly the size of this grid is something that can be decided. However none of the game elements describe physical characteristics of the Port of Rotterdam. The size of the world and the location of the agents is meaningless in the simulation model made for this thesis, except that it can be used to display an animation.

Time, just as space, is discretised in Netlogo, meaning that states of variables change on particular instances of time (called ticks) and that no changes happen between these ticks. The time these ticks represent can be freely specified by the modeller. Normally, one would choose a number of ticks that the model has to run based on the relevant timeframe, or enter a stopping condition in the code. However the timeframe of the process to coordinate the departure order is not relevant to generate the outcomes. All decisions can be taken at the same time step (or tick) in the simulation. The game thus takes place in 1 tick.

5.2.2 TRANSLATING MATHEMATICAL MODELS TO SIMULATION MODEL

The mathematical models presented in the previous chapter are spreadsheet based. Because Netlogo is a programmable modelling environment, the cell references of the
models cannot be copied to the simulation model. Instead the formulas need to be rewritten with the use of new variables. This paragraph will give a brief explanation of how that translation is done. Appendix G contains the entire Netlogo code for the model.

The simulation model’s interface (shown in figure 21) contains the grid with seven symbols representing players, and a telephone that moves to the player making a decision in the animation (see figure 22). The scenario variables identified in paragraph 4.5.2 also need to be incorporated in the simulation. By implementing them as ‘choosers’ in the interface, they can be referred to in the code. The upper four scenario variables in figure 22 affect the actions available to the players. The effect of these input variables do not necessarily have to be integrated in the code, but can be tested later on by filtering the output of the simulation on the available actions of the players. For example, if tugboats are not available, the tugboat company always either delays the departure order by setting a later ETD or by responding late to an order. By applying a filter only the outcomes in which these actions are taken can be taken into account. The ship size variable meanwhile has an influence on the cost parameters and thus has to be taken into account in the code.

![Figure 21: Simulation model interface](image)

On the right hand side of the interface, several ‘sliders’ allows one to adjust the actions taken by the agents. These sliders have increments of 0.5, in accordance with the chosen time scale of action (see paragraph 4.6.1). The actions are included in the ‘go’ procedure. In this procedure first, one-by-one all agents set a time-variable to a certain value. That value is based on the time the previous agent has set and the value of the decision variable sliders discussed earlier. Furthermore, a telephone symbol is animated to move to each of the players, as they set a value (see also figure 22 for the animation steps). To exemplify, in the following piece of code the shipping company sets its time-variable;

```netlogo
to terminal-communicates-order
  ask messages [move-to terminal 0] ;; animation
  set communicated-end-of-ops-time (actual-end-of-ops-time + decision-terminal)
  set ETD-by-terminal communicated-end-of-ops-time + 0.25
end```
Once every player has set a time variable, the highest time set forms the departure time. Based on the actions taken, the delay and cost calculation can be done. This requires that the formulas behind the cost and delay matrices presented in paragraph 4.6 are translated to Netlogo code. Table 4 in paragraph 4.6.2 shows a delay matrix with 77 cells. These 77 cells all need to be assigned as a different variable name to be called upon by the simulation model code. The cells that show the delay caused by the terminal to other players translates to the following variables:

- delay-terminal-to-terminal
- delay-terminal-to-shipping-company
- delay-terminal-to-shipping-agent
- delay-terminal-to-port-authority
- delay-terminal-to-pilot
- delay-terminal-to-tugboat-company
- delay-terminal-to-boatmen

In the same manner the following formula calculates the total delay of a terminal:
The mathematical model specified to calculate costs is then translated in a similar fashion.

### 5.2.3 EXPERIMENTAL DESIGN

As explained in paragraph 4.6.3, all possible combinations of actions and input variables need to be run by the simulation model to investigate the research question and strategic hypotheses. Because there are no stochastic variables in the model, no replications of runs are needed. The previous paragraph explained that some of the input variables do not have to be included in the experimental design, because the outcomes can later be filtered to reflect the same effect. This limits the solution space, keeping it manageable.

For each model run in this experiment, the actions taken, the value of the input variables, the times communicated by the players, the departure time, the delay experienced by each player and the cost experienced by each player have to be measured. Appendix E describes the specific variables included in this experimental design.

The output of the simulation model and the experimental design can be made clear by showing a few runs. Table 5 shows the actions taken by the different players and the input variable ship size. The values for the actions state the difference between the time communicated by a player and the time they received. So if the terminal shows decision - 0.5 that means that an EoOT is communicated that is half an hour lower than the AEoOT. To check whether the actions have the right effect, the experiment also reports the communicated times. These are shown in table 6. Because Netlogo cannot format numbers as times (i.e. 00:00 format), all times are converted to ‘standard’ numbers. A value of 14,75 thus means 14:45h. The delay every player experiences is depicted by table 7. The sum of all delays, the system delay, is also included. Note that delays are presented in hours. Finally, the cost experienced by every player and the total system can be seen in table 8. Costs are presented in euro.

<table>
<thead>
<tr>
<th>Table 5: Actions taken in experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>run number</td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 6: Communicated times in experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>---------------</td>
</tr>
</tbody>
</table>
### 5.3 VERIFICATION

Before the generated outcomes can be analysed, it must be checked whether the simulation model is specified correctly. The animation implemented in the simulation model helps verifying if the departure order process has been modelled in accordance with chapter 4. Moreover the actions and the time scale of these actions available to the players should be the same as specified in chapter 4. That should materialise in the decision parameter only attaining values of -0.5, 0 and 0.5. Furthermore the output provided by the mathematical models of delay and cost can be compared with the output of the simulation model. These outcomes should be equal. More specifically, the influence of the actions on delays need to meet the following criteria; no departures should take place before the AEoOT, neither should there be time gains higher than 15 minutes for the shipping company and terminal and not every action can lead to time gains in the process. Some specific criteria for the verification of the effects in terms of costs are; the cost parameters that are used are equal to those used in the mathematical model of paragraph 4.6.2 and players only receive money if they are delayed by another player (i.e. delay should be non-negative). The Netlogo code specified in Appendix G passes these tests, the outcomes the simulation model generated can be analysed.
6 SIMULATION OUTCOMES

The outcomes generated by the simulation model will be analysed in this chapter. Specifically, the strategic hypotheses formulated at the beginning of chapter 4 need to be tested. The approach described in paragraph 4.6.3 is to be used for that. The first paragraph of this chapter will cover the hypothesis related to the terminal’s behaviour. After that the two hypotheses about the shipping company are discussed. Next, the hypothesis that says something about the other players is covered. The fourth paragraph analyses the sensitivity of the model to parameter changes. The last paragraph tests the hypothesis that is related to the port as a whole.

Not all graphs and tables related to the analysis are included in this document (for readability purposes). An online appendix contains the spreadsheets in which all relevant graphs and tables can be generated as well as the netlogo models used to generate the data. To access the online appendix, use the following link: https://www.dropbox.com/sh/14952ceuk1tyoge/AAA6kHNxx8KrekVXXZJIAAlp1a?dl=0

6.1 INCENTIVES TERMINAL

Strategic hypothesis 1 states: Container terminals have an incentive (expressed in time and money) to communicate an expected end-of-ops-time that is a lower estimate of the end-of-ops-time than they actually perceive to be true (i.e. communicate an unreliable ETD). Figure 23 meanwhile shows the total delay and the total cost experienced by the terminal, depending on the choice the terminal makes. To support the hypothesis the results need to show that choice -0,5 (low estimate) provides lower costs and delay for the terminal than choice 0 (best estimate) or choice 0,5 (high estimate), regardless of the choices the other players make.

Figure 23: Influence of terminal’s choice

At first glance it does not seem as if the hypothesis holds, since there are outcomes associated with choice 0 that have a lower cost and lower delay than outcomes associated with choice -0,5. So by looking at the graph you cannot say choice -0,5 always provide lower delays or cost than other choices. However a fair comparison cannot be done purely by
looking at the graph. What must be kept in mind is that the experimental design consist of all players choosing all actions available to them. To then analyse the influence of an action of a player on his cost and delay, that action must be considered the independent variable. The actions of other players must remain equal. In game theoretic terms the paths (a path is a single combination of choices from the beginning to the end of the game tree) that consist of the same actions, except for the action that is under investigation should be compared. Figure 24, visualises that. If a certain action results in better outcomes, by comparing them in the way stated above, that action always results in better outcomes for the player taking it.

Should an action not always provide better outcomes than other actions, the hypothesis can potentially still be uphold if the difference between theoretical outcomes and reality is taken into account. Paragraph 4.6.3 already explained that the frequency of a certain outcome in the model does not say anything about how often that outcome happens in reality. It could for example very well be that a certain path in reality occurs 99% of the time. Should choice 0 deliver the best results for the terminal with this path, strategic hypothesis 1 is falsified. This of course also works the other way around; should an outcome that falsifies the hypothesis not occur in reality all that often, the hypothesis could be upheld (with some reservations). In other words, the chances of certain outcomes have to be considered, to estimate the expected value of a certain action.

![Figure 24: Comparison of paths](image)

Returning to the analysis of the simulation outcomes, the outcomes with similar paths (except for the decision of the terminal) are matched in order to be able to draw a conclusion. Choice -0.5 (i.e. communicate unreliably) proves to lead to better results in all of the matched outcomes than the other choice available to the terminal. This supports the strategic hypothesis.

**FEEDBACK OF ACTIONS**

Chapter 4 explained how the use of input scenarios could reflect the fact that the departure order game is played many times a day and the fact that the outcomes in one game have an effect on the next. If for example, we accept that terminals do have an incentive to communicate an unreliable end of operations time and that terminals act according to this incentive, this will lead to a decrease in effective capacity of nautical service providers. It would be interesting to see how different starting conditions, relating to the availability of nautical service providers, will affect the incentives of players. In other words; ‘will players still act the same if players are delayed in previous games?’.
To investigate the effect of these inputs on the behaviour of player the model outcomes are filtered on choices that certain players make. If the input is that nautical service providers are unavailable, only the outcomes in which the tugboat-company and or the pilot respond late to the departure order are studied. For studying the effects of capacity arrangements, the outcomes were filtered on whether the tugboat-company and pilot set a later ETD. Similarly a scenario in which waterway capacity is scarce can be reflected by the Port Authority setting a later ETD.

The outcomes acquired when filtering the outcomes in the manner stated above show that the terminal has an incentive to communicate a low estimate of the end of operations time, no matter what the input scenario is (the related graphs can be generated in the online appendix). In fact, the outcomes for the terminal are rather insensitive to the input scenarios. Again, we must remember that in reality games are linked. The expected value of an action (i.e. the incentive expressed in time and money) is therefore not wholly determined by the outcome of a single game. The outcomes that a terminal can potentially achieve in a situation in which the nautical service providers are not delayed are rated higher than the outcomes in which they are delayed. If a terminal’s action can lead to there being enough capacity of NSP in subsequent games, is then the expected value of communicating reliably higher than communicating unreliably?

Expressing or estimating that expected value is difficult. It is not so much the achievable value in each situation (NSP delayed or not), but rather the effect the choice of a terminal has on the capacity of NSP, given all the other influences on that capacity (e.g. other terminals). The situation is quite comparable to problems with common-pool resources. Take for example a fish stock (NSP) that is fished by several fisheries (terminals). Each fishery has the incentive to fish as much as they can, up to the point that the stock is threatened to extinction by overfishing (unreliable communication). At one point the expected value of a fishery (terminal) to fish less (reliable communication) is higher, due to potential payoffs in the future. That payoff is however dependent on how other fisheries will act, and how far into the future these companies will want to look.

It is not entirely clear how terminals act during times in which a capacity arrangement is in effect. The delay registration shows that the percentage of delays caused by terminals is decreased in the case there is a capacity arrangement in effect (from 61% of delays to 26%). What cannot be concluded from this is that terminals change their behaviour. The difference in percentage of delays registered can be merely caused by NSP having a higher change of causing delays. At the same time the capacity arrangement requires causes the timeframe of a departure order to go from two to three hours. This means that terminals have to communicate an end-of-operations-time with a higher degree of uncertainty.

What can be said is that delays caused by terminals are still present in these situations. If we assume that incentives are a reasonable explanation for behaviour in ‘normal’ situations, it seems not far-fetched that terminals will also act according to their incentives during capacity arrangements. Thus some of the delay will be caused by terminals deliberately communicating unreliable. Some terminal will have the idea that their expected value of acting reliable in those situation is higher if they act reliable. Others will see the potential for free-riding on their behaviour. Much of it will be dependent on how terminals see their influence on the capacity of NSP. A nautical traffic simulation study could make this influence visible. It seems probable that such a study has already been done by one of the chain-partners. In any case, strategic hypothesis 1 is supported. Container terminals have an incentive to communicate an unreliable ETD, regardless of the actions of the other player and regardless of the input scenarios.
6.2 INCENTIVE SHIPPING COMPANY

Two strategic hypotheses relating to shipping companies are formulated in chapter 4. The first states that “Shipping companies have an incentive (expressed in time and money) to communicate an estimate time of departure that is lower than the ETD they actually perceive to be true (i.e. communicate an unreliable ETD)”. As explained in paragraph 4.1.1, the size of a ship is a determining factor in the revenue it generates for a shipping company. There are some clues (see paragraph 4.1.1) to suspect that there is a ship size where the revenue generated by ordering a departure too early does not cover the penalties other player charge for the caused delay. As such the second strategic hypotheses states: “Shipping companies with smaller ships don’t have an incentive (expressed in time and money) to communicate an estimated time of departure that is lower than the ETD they actually perceive to be true (i.e. communicate an unreliable ETD)”. Note that the ship sizes taken into account are 1500 TEU and 16000 TEU.

The simulation output for the shipping company show similar outcomes in terms of delay as for the terminal (see figure 25). If shipping companies only care about the port stay time of their ships, they would have to communicate a ‘too early’ ETD. Should a shipping company also care about the delay cost experienced, the conclusion becomes less obvious. In total there are 34 outcomes in which the delay cost for a shipping company are higher in case it chooses option -0.5 instead of 0. By describing what happens in these 34 outcomes, the strategic hypothesis about shipping companies can perhaps still be supported. 

Figure 25: Influence of Shipping Company’s choice

Table 9: frequency table shipping company outcomes

<table>
<thead>
<tr>
<th>Choices made</th>
<th>Terminal</th>
<th>shipping company</th>
<th>shipping agent</th>
<th>port authority</th>
<th>pilot</th>
<th>tugboat company</th>
<th>Pilot</th>
<th>tugboat company (action 2)</th>
<th>Pilot (action 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.5</td>
<td>34</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>34</td>
<td>34</td>
<td>2</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>0.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>32</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
</tbody>
</table>
Table 9 shows the frequency of actions taken by the different players in the 34 outcomes of interest. In this pocket of outcomes the two different ship sizes are equally represented. Moreover the terminal always communicates unreliably, which is not unlikely given the conclusion on strategic hypothesis 1. Furthermore the Port Authority almost always sets a later ETD. Which is an infrequent occurrence in reality. (B. van Scherpenzeel, personal communication, 28, July, 2015). The pilots and tugboat company meanwhile set a later ETD in half of the outcomes. Something that is not unheard of. These players also show up later than the ETD, in fifty percent of the outcomes. The delay data registration (see paragraph 2.3) shows that this does happen. Most importantly, the pocket of outcomes also includes an outcome in which everything goes according to planning and one in which only the terminal communicates unreliably. This seem to be the most common outcomes achieved in reality. Seeing the above characterisation it leads to the conclusion that the 34 outcomes that are not supportive of the strategic hypothesis 2 and 3 do definitely happen in reality. Hence strategic hypothesis 2 and 3 are strictly speaking falsified; there is no incentive in time AND delay cost for shipping companies to communicate an unrealistic ETD.

At the same time it must be said that the difference in delay cost achieved by choosing option ‘0’ is quite small. For 1500 TEU ships the costs amount to roughly €350 and for 16000 TEU ships an amount of roughly €650 is achieved in the model. For smaller ships (much smaller than 1500 TEU) this magnitude of cost can be a reason to communicate fairly, while for bigger ships this cost seem negligible to the fuel cost. A more costly, but earlier departure can easily be compensated by lower speeds at sea (see for fuel consumption per metric tons Riodrigue [2013] and for the average bunker cost per metric ton Germanischer Lloyd [2011]). Because of these reason shipping companies mainly focus on minimizing the port stay time (Ben van Scherpenzeel, 28, July, 2015). The model shows that the ‘best’ way for a shipping company to minimize the port stay time of a ship is to communicate unreliable. Acting like this will not lead to too high costs for either of the ship-sizes included in the model. The idea that the incentives of players can be an explanation for delay in the port (i.e. strategic hypothesis 2) is again supported.

FEEDBACK OF ACTIONS

Neither of the input scenarios are able to change the conclusion on the incentive of the shipping company (see the online appendix for the related graphs). The number of outcomes that are not in line with strategic hypothesis 2 actually decrease in the scenarios tested. Also similar as in the previous paragraph is that the difference in cost experienced in these outcomes are small. A shipping company driven by minimizing time should always take action -0,5 if a single game is taken into account. However, as touched upon earlier, players do not play a single game. The outcomes that a shipping company can potentially achieve in a situation in which the nautical service providers are not delayed are rated higher than the outcomes in which they are delayed. The actions of a shipping company meanwhile influence the capacity of the NSP. The expected value of acting unreliable could thus be lower than the model outcomes suggest. It depends on a shipping companies view on how the influence it can exercise on the port system. Here a difference might be seen between infrequently and frequent visiting ships or shipping companies. This could be topic of further research. Having said that, the incentives shown by the model outcomes do offer a feasible explanation for shipping companies communicating an unreliable ETD. Which means that strategic hypothesis is supported. The outcomes however do not show that a shipping company has an incentive to act differently if it regards a 1500 TEU ship compared to when it regards a 16000 TEU ship. Strategic hypothesis 3 is thus falsified. There is still reason to suspect that there is ship size at which the incentives flip from communicating
unreliable to unreliable, but not for the ship sizes included in this model. Where that point lies exactly is unclear, but beyond the scope of this research to further investigate.

6.3 INCENTIVES OTHER PLAYERS

The fourth strategic hypothesis groups the remaining players. It states that “Other parties experience damage from unreliable departure orders, but their financial damages are relatively low. The incentive to counteract unreliable departure order is thereby existent, but small”. As explaining in paragraph 4.1.1, this conclusion is expected because none of the experts interviewed put forward the incentives of these other parties as an explanation for delay in ship handling. Another reason is that these parties are more active in participating in various kinds of initiatives to change the ship handling process as a whole (e.g. the Pronto project). This suggests that these parties are not able or willing to act according to direct cost and delay incentives in the current process. The graphs showing the influence of the players on their outcomes can be found in appendix H.

The effect of the input variables on the outcomes of the players covered in this paragraph. The reason for that is because the input variables sometimes leaves these players with no choice. It is futile to research what action players are driven to if there is only one action available to them.

PORT AUTHORITY

On 36 occasions the model outputs an outcome for the Port Authority that either shows a smaller delay or lower cost for choice rather 0.5 than choice 0 (see table 10). In other words, 36 outcomes that could be used to say that the Port Authority has an incentive to set a later ETD (communicate unreliably). In all these outcomes the terminal or shipping company acts unreliable. The previous paragraphs have shown that both players have an incentive to do that. That does not necessarily mean that they always act according that incentive. For a terminal it would for example only be useful to communicate an (too) early end of operations time if there is no slack in the berth planning. The point is that these outcomes aren’t unrealistic but other outcomes do occur in reality. One example would be the situation in which every player communicates reliably. Despite the focus on delay in this report, most of the times the coordination between the chain-partners does go well. Unfortunately the likelihood of a certain outcome cannot be described quantitatively, as it is not registered nor was it feasible to measure it in the timeframe of this thesis. In this case this leads to the problem that is unclear whether action 0 or action 0.5 will result in a higher expected value for the Port Authority.

A good argument can be made for the Port Authority having an incentive to not deliberately set a later ETD. First of all a comparison in the cost achieved with the two actions available to the Port Authority reveal that the maximum cost achieved with choice 0 is around €1200, compared to a maximum delay cost of €5000 for choice 0.5. A risk averse player would have an incentive to choose action 0. Always setting a later ETD would also delay the shipping companies, which in turn could lead to these companies turning to a rival port. Losing a customer would significantly lower the expected value of the action that caused it. Projects such as ‘Het Schip Centraal’, initiated by the Port Authority provide evidence for the fact that the goal is to reduce delays for the shipping company. Not so much for themselves. Moreover, several interviews didn’t point out that the Port Authority sets later ETDs very often either.
PILOT

Pilots have two decision moments in the game, both will be discussed here. The findings for the first decision are quite similar to those of the Port Authority. There are 67 outcomes in which the pilot would benefit (either in cost or delay) for setting a later ETD. If the outcomes in which the terminal or shipping company takes an unlikely action are removed, 48 outcomes remain (see table 11). The outcome in which every player communicates reliably is once again not included. The maximum cost gain that can be achieved by setting a later ETD is around €1700. However it is unclear what the expected value of each action is because there is no way of assigning a chance to an outcome currently.

It is more likely that pilots see their expected value for setting a later ETD lower than that of setting a ‘normal’ ETD because of the same reason as stated for the Port Authority. First of all the maximum cost that can be achieved with choice 0 are much smaller (€1500 vs €6000). Secondly, the payoffs of future games become more uncertain, the more delay a shipping company experiences (a shipping company could do business at another port). Pilots meanwhile can decrease the chance for that by always choosing action 0. Hence there is likely no incentive to set a later ETD for a departure order.

The second decision that pilots have to make is whether to respond on time or not to the departure order. There are no model outcomes in which the pilot would benefit, in cost or in delay, from responding later to the order.

TUGBOAT COMPANY

The tugboat company also has two decision moments. For the first decision there are 12 outcomes which show that a tugboat company can benefit from setting a later ETD (see table 12). All these 12 outcomes lead to less delay for the tugboat company (up to 0.5 hours), and sometimes to lesser cost (up to €800). The outcomes in which every player coordinates reliably is not included. Because the exact chance of these outcomes is unknown, the expected value of the actions of the tugboat company are unknown.

It is more likely that the tugboat has more to gain from choosing to act reliably because of two reasons; firstly the cost that can be achieved with choice 0 are smaller (max 3000 versus max 3500). The other reason is that future payoffs for the tugboat company

---

### Table 10: Frequency table Port Authority Outcomes

<table>
<thead>
<tr>
<th>Choices made</th>
<th>Terminal</th>
<th>shipping company</th>
<th>shipping agent</th>
<th>port authority</th>
<th>pilot</th>
<th>tugboat-company</th>
<th>Pilot (action 2)</th>
<th>tugboat-company (action 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.5</td>
<td>34</td>
<td>34</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>2</td>
<td>36</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>0.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
</tbody>
</table>

---

### Table 11: Frequency table Pilot outcomes

<table>
<thead>
<tr>
<th>Choices made</th>
<th>Terminal</th>
<th>shipping company</th>
<th>shipping agent</th>
<th>port authority</th>
<th>pilot</th>
<th>tugboat-company</th>
<th>Pilot (action 2)</th>
<th>tugboat-company (action 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.5</td>
<td>40</td>
<td>38</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>8</td>
<td>10</td>
<td>48</td>
<td>30</td>
<td>25</td>
<td>23</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>0.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>18</td>
<td>23</td>
<td>25</td>
<td>26</td>
<td>26</td>
</tr>
</tbody>
</table>
might be at risk if communication is done unreliably. To exemplify; during the time in which this report was written, a big shipping company switched from one tugboat-company and back again. A shipping company can relatively easily switch to another tugboat company, but what is a tugboat company going to do in case it is displeased with how a shipping company act? Refusing service to a shipping company because they act strategically would probably not be the wisest decision in a highly competitive tugging business. A pilot can’t refuse service to a shipping company either, they are obligated by law to service ships.

The second decision that tugboat companies have to make is whether to respond on time or not to the departure order. There are no model outcomes in which the pilot would benefit, in cost or in delay, from responding later to the order.

<table>
<thead>
<tr>
<th>Players</th>
<th>Terminal shipping company</th>
<th>Shipping agent</th>
<th>Port authority</th>
<th>Pilot</th>
<th>Tugboat company (action 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choices made</td>
<td>-0.5</td>
<td>6</td>
<td>10</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>-0.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

### CONCLUSION

Strategic hypothesis 4 is supported by the findings about the outcomes of for the Port Authority, Pilot and Tugboat Company. For all players, there is a small portion of outcomes that provide better results if they would set a later ETD (effectively counteracting unreliable departure orders). This is not the case for the most probable outcome. Furthermore, the benefit of setting a later ETD are shown to be small. Moreover, setting a later ETD in other outcomes would result in much higher costs for the respective players. The above leads to the conclusion that these parties indeed have a small incentive to counteract unreliable departure order, but are not likely to act upon this incentive.

### 6.4 SENSITIVITY

To test the robustness of the findings depicted in the previous paragraphs the model is subjected to some parameter changes. First the sensitivity to changes in the time scale of actions is tested, then the sensitivity to changes in cost parameters is described. The related graphs can be generated in the online appendix. The result will be discussed below.

---

**TIME SCALE**

Currently the actions within the model are specified on a discrete scale (±30, ±0 and ±30 minutes). In reality players have an unlimited continuous scale of actions to their disposal. What will happen if the scale of action available to the players changes? The scale has been both doubled and halved in an attempt to investigate the sensitivity to the scale choice (i.e. a scale of ±15, ±0 and ±15 minutes and a scale of ±60, 0 and ±60 minutes).

The delay functions specified in the model are mostly numerically sensitive, but there not behavioural sensitive. Meaning that the delay acquired is increased or decreased for all actions of a player to a mostly equal extent. A change in the findings from the base case (behaviour) would only occur if the delay achieved with a certain action increases or decreases more relative to the increase or decreases for another action. For example if action -0,5 for a terminal result in higher delays with a larger time scale than the delay
achieved with action 0. The reason for this behavioural insensitivity is that the delay calculation are mostly linear. To give an example; Both the terminal and the shipping company make choice -0,5, while the tugboat company makes choice 0,5. This leads to a delay of 0,5 for the tugboat-company. If the time scale of actions is doubled the delay for the tugboat is also doubled (-1 -1 +1= 1). However the calculation are not always that linear, the achievable time gains for example are constraint. Doubling the scale of action will not double the time gain.

The cost functions meanwhile are the product of a certain delay time and a cost parameter. Increases in the scale of action can lead to non-proportional increases in cost because the delay function can show that behaviour. Overall, the findings from the previous paragraphs are quite insensitive to the changes. The effects will be briefly discussed per player;

**Terminal**: Neither the larger nor the smaller time scale led to a situation in which it would be beneficial for the terminal to communicate reliably, rather than communicate an early end of operations time. The earlier findings are thereby unchanged.

**Shipping Company**: Strategic hypothesis 2 is actually strengthened with both a smaller and larger time scale. In both situations there are not outcomes in which the shipping company achieves better result by communicated reliably, rather than unreliably.

**Port Authority**: A larger time scale leads to 36 outcomes that show an incentive for the port authority to set a later ETD. These outcomes consist of the same combination of choices made by players as before. The cost differences between the two actions are larger, but not enough to warrant a change in conclusion. With a smaller time scale the number of outcomes that show an incentive for unreliable behaviour decreases to two. Both will only lead to a lower delay (not costs) for the Port Authority.

**Pilot**: For the first action that the pilot takes, both time scale changes reduce the number of outcomes that show an incentive for setting a later ETD (from 48 to 20 in case of the larger scale and to 0 in case of the smaller scale). The outcome in which everyone communicates reliably is still not included. Hence the conclusion is not changed. There are no changes in the findings for the second action, except for some numerical sensitivity.

**Tugboat Company**: A larger scale leads to the same 12 outcomes that show an incentive for setting a later ETD as found earlier. A smaller scale decreases that number of outcomes to two. For the second action the larger scale results in no outcomes that show an incentive for strategic behaviour. While a smaller scale shows 19 outcomes in which a tugboat would have an incentive to respond later to a departure order. The same argumentation as before can be used to not change the conclusion on the basis of these 19 outcomes. The first reason is that the more probable outcomes lie outside of this pocket of 19 outcomes. Secondly, the cost that can be achieved with choice 0 are much smaller (maximum of €700 versus a maximum €9000). Lastly, the future payoffs for the tugboat company might be at risk if communication is done unreliably. The potential cost and time gain reached by acting unreliable are not very likely to exceed the risks. Taking into account the results for the port authority, pilot and tugboat Company, strategic hypothesis 4 is robust for the changes to the time scale.

---

**COSTS**

The formula used to calculate the experienced cost per player uses two cost parameters; the delay cost per hour for a player and the chargeable cost for a player (see paragraph 4.6.2). To keep the sensitivity analyse manageable and useful, the cost parameters investigated are limited to the delay cost per hour of the terminal and that of the shipping company. Firstly that choice is made because the chargeable cost in that formula are relatively well known (specified in documents). Moreover these represent a much smaller part of the cost of players compared to the hourly delay cost. The behaviour of the terminal
and shipping company is therefore likely very insensitive to changes in the cost that other players can charge them. Changing the hourly cost of delays is more likely to lead to a change in behaviour. Given the findings for the Port Authority and the NSP in the previous paragraphs, it is not likely that the behaviour as shown by the model will be sensitive to changes in costs. Therefore the sensitivity analysis will only be conducted on the cost per hour of delay for the terminal and shipping company. Both cost parameters are varied by 50%, in either direction.

The effect of the cost change of the terminal and shipping company are studied in isolation and simultaneously. The conclusion for the terminal and the shipping are found to be robust enough to withstand a change in cost parameter of 50%. The model outcomes still show that the terminal has an incentive to communicate unreliable. If the cost per hour delay of a shipping company are cut in half, there are 43 outcomes in which the shipping company has a cost incentive to communicate reliably. These 43 outcomes have almost the same characteristics as the pocket of outcomes identified in paragraph 6.2, at the discussion of the base case result for the shipping company. The conclusion also remains the same; the outcomes are probable and might disprove strategic hypothesis 2 (shipping company has an time AND cost incentive to act unreliable), but the model still shows that the ‘best’ way for a shipping company to minimize the port stay time of a ship is to communicate unreliable. Furthermore a shipping company will primarily focus on minimizing the port stay time, because the extra delay cost the shipping company might experience due to communicating unreliable can easily be compensated by adjusting the sailing speed at sea. The conclusion in regard to strategic hypothesis 3 also remains unchanged if by the sensitivity analysis. The outcomes do not show that a shipping company has an incentive to act differently if it regards a 1500 TEU ship compared to when it regards a 16000 TEU ship.

6.5 VALUE CREATION

The previous paragraphs made clear what the incentives for each ship handling player are. This paragraph will give some attention to what the implications are for the ship handling system as a whole, should parties act according to their incentives. The last strategic hypothesis (5) is related to that. That states “These incentives lead to unreliable departure orders, which result in pareto optimal outcomes.”. The incentives of the terminal and shipping company have shown to be to choose option ‘-0,5’, or in other words ‘order a departure too early’. Since none of the other players have an incentive to counteract that choice (i.e. choose option 0,5) , the result will be an unreliable departure order. This confirms the first part of the strategic hypothesis

The system delay and system costs (sum of delay and cost of all individual players) in that situation are 2.25 hours and € -3000 (rounded) respectively. This is not a bad outcome, especially regarding system costs, in comparison with all achievable outcomes. This is of course caused by the fact that the terminal and shipping company are delayed the least (or even gain time) and create the most value of all the parties. Nevertheless, there is room for improvement. A situation in which coordination fails naturally leads to inefficiencies, which are shown by the model outcomes. The second part of the hypothesis is confirmed by the model; the situation in which players act according to their incentives lead to a pareto optimal outcome. This means that no player can benefit from a move change, without at least one player getting worse off. The implication is that remedying the situation with moves in the game is difficult. Chapter 8 discusses some policy options that could help in reducing unreliable departure order.
7 VALIDATION

This chapter will cover the validation of the game. The first paragraph will explain that the validation needs to be split up into three parts. Namely, validation of the game, validation of the findings resulting from the game, and the internal validity of the game. The paragraph thereafter explains what methods other authors use to validate GSM and what methods are used in this chapter. Subsequently the three parts of validation each are explained in a separate paragraph. The last paragraph expresses judgement on how good the game is and describes the use of the game.

7.1 WHAT SHOULD BE VALIDATED

The primary goal of the game is to make inferences about real life behaviour of parties in the ship handling process in order to formulate recommendations for improvement. In the game the values and assumptions about players drive their behaviour. By implementing this game in a simulation model, the incentives for players to act in a certain way can be investigated. To answer the main research question, the assumption needs to be made that these incentives can explain real world behaviour. Figure 26 shows the inferred relation between game, model findings and behaviour in reality. The dotted lines signify the relations that need to be validated.

![Figure 26: Inferred relation game and behaviour in reality](image)

Validation of the answer to the main research question then entails proving three things. First of all, the game is an accurate representation of the departure order process. In other words, the construct and content validity of the game needs to be tested. Does the model measure the cost and delay in the right way? Are all relevant players included? Are the boundaries correct? Etc. Secondly, the conclusions in chapter 6 about the incentives of players must logically follow from the outcomes. Among else that means that the conclusions are not sensitive to parameter changes. Again the construct validity is tested. Lastly, the internal validity of the model has to be discussed. An internally valid model means that the conclusions on player behaviour in the model can be generalised to reality. This can be done if the players act according to the incentives specified in the model in reality, in the same manner as in the model. Meanwhile, an externally valid model means that the conclusions can be generalised to other situations and other people. Chapter 10 will discuss the possibilities for that.

7.2 VALIDATING GAME STRUCTURING METHODS

Several authors mention that validating PSMs is difficult. This is partly because the output of PSM applications is often intangible [Ackermann, 2012]. PSMs are prone to deliver this type of result because they “aim for exploration, learning and commitment rather than
Validating GSMs is complicated further because strategic intentions, hidden agendas and emotional factors play a role in the problems investigated by GSMs [Bots & Hermans, 2003; Cunningham et al., 2015]. This will also become apparent in paragraph 7.5. While there is a desire for validation and evaluation methods, there is no consensus on how to do it [Lei & Thissen, 2009; White, 2006]. Lei and Thissen [2009] actually state that validating GSMs is underdeveloped.

7.3 GAME
To test whether the game is an accurate representation of the departure order process, some of the sub-questions formulated in paragraph 2.7.2 can be used. By shortly reiterating what assumptions, design choices, and sources underlie the answers to these questions the validity of them can be discussed. The sub-questions relevant to the specification of the game are the following:

a. Who are the players?
b. Which actions do they have?
c. In what order do these actions take place?
d. What is the information players have?
e. What are the outcomes to which parties are driven by their payoffs?

Not addressed by a sub-question, but nevertheless important to discuss here are the boundaries of the game. The game only describes the coordination between players, not the internal business routines of these players (e.g. capacity resource management). This focus on coordination reduces the complexity a lot, keeping the research manageable within the timeframe. In reality the internal business routines have an effect on the decisions parties make. Furthermore the representation of the physical system is quite simplistic. For example, in real life ships break down and wind, tide and location have an influence on the services parties can deliver. However these scoping choices can be argued for because the delay in ship handling can mostly be accounted for by the interaction of the several parties involved [Roo, 2014].

Another attempt to reduce the complexity of the model was to not dynamically link multiple games. As explained in paragraph 4.2, the outcomes of one departure order game can have an effect on the next game. The supply chain effect to which is referred can be replicated by incorporating input variables in the game. The game thus takes into account that it is not an isolated part in the whole ship handling chain. This approach does lead to difficulties in analysing the outcomes, which is something the next paragraph will discuss. Most importantly however, the boundaries of the game represent reality to some extent.

Regarding the first sub-question (a), the game focusses on the players directly involved in the departure process of a ship. The inventory of players was made with the help of a process diagram made by the Port Authority and experts within the Port Authority [Grund, 2014]. Similarly the order of play can also be checked via that process diagram (sub-question c).

In chapter 4 the game was characterised as a certain (i.e. ‘certain’ in game theoretic terms) game with incomplete, imperfect and asymmetric information (sub-question d). This characterisation has been deemed correct by several experts at the port Authority. One of the most crucial assumptions about information is that the terminal knows the actual end of operations time. In reality that time is uncertain to some extent, even for the terminal. In first instance the design choice was made to not introduce stochastic variables in the
model, to keep the results manageable in size. The following example explains why incorporating a stochastic actual end of operation time that is unknown to the terminal does not affect the findings for the terminal.

In order to improve their planning capacity and berth utilisation a terminal will want to chart the uncertainty of their terminal operation. This means that a terminal knows how the uncertainty of the operations time is distributed, given some ship characteristics. Suppose that the operations time is normally distributed with a mean of 15 hours and a standard deviation of 1 hour (see figure 27). If the actual operation time is 14 hours and 16 hours respectively, what would be the best choice for the terminal? Act reliable or unreliable? Table 13 shows the cost and delay for the terminal in both situations for a 1500 TEU ship. Note that the cost of the terminal are partly formed by the penalty it has to pay to the shipping company for caused delay. The table shows that the terminal has a cost and delay incentive over two outcomes to communicate an early end of operations time. By doing that, the terminal displaces some risk on delay to the shipping company, which can be easily compensated by the terminal because their delay cost per hour is several times higher than that of other players. This exemplifies that even with stochastic end of operations time, the findings for the terminal will remain unchanged.

![Figure 27: Example chance distribution operations time of a terminal](image)

<table>
<thead>
<tr>
<th>Decision terminal</th>
<th>Actual end of operation time [hours]</th>
<th>14:00</th>
<th>16:00</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both</td>
<td>Perceived end of operations time [hours]</td>
<td>15:00</td>
<td>15:00</td>
<td>n.a.</td>
</tr>
<tr>
<td>-0,5</td>
<td>Cost terminal [€] (rounded)</td>
<td>9000</td>
<td>19000</td>
<td>28000</td>
</tr>
<tr>
<td></td>
<td>Delay terminal [hours]</td>
<td>0:30</td>
<td>1:00</td>
<td>1:30</td>
</tr>
<tr>
<td></td>
<td>Delay shipping company [hours]</td>
<td>0:30</td>
<td>1:30</td>
<td>2:00</td>
</tr>
<tr>
<td>0</td>
<td>Cost terminal [€] (rounded)</td>
<td>18000</td>
<td>18000</td>
<td>36000</td>
</tr>
<tr>
<td></td>
<td>Delay terminal [hours]</td>
<td>1:00</td>
<td>1:00</td>
<td>2:00</td>
</tr>
<tr>
<td></td>
<td>Delay shipping company [hours]</td>
<td>1:00</td>
<td>1:00</td>
<td>2:00</td>
</tr>
</tbody>
</table>

The actions available to the players in the game consist of manipulating a departure time (sub-question b). The actions available to the players were seen as conceivable by two experts of the Port Authority (Jacob Bac and Ben van Scherpenzeel, personal communication, n.d.). The boatmen and the shipping agent have been modelled as pseudo players, as they practically never manipulate the departure time, without informing the other players about that. These actions were therefor seen as infeasible. Thus the model shows that the shipping agent and boatmen have no influence on delays. In reality players do communicate about much more than the departure time (e.g. a shipping agent also coordinates about cargo information and drafts of ships). As shown by paragraph 2.3, there is delay that can be attributed to the coordination of shipping agents and boatmen, although it is a relatively small part of the total delay. Moreover, including actions in the
game to capture this communication is not obvious in light of the main research question. It is not clear how incentives of players are related to coordinating this type information. Delay caused by this coordination is less likely to be rooted in strategic behaviour. The modelling of these players as pseudo players is therefore not consequential for the validity of the game.

The actions in the game lead to cost and delay. The question is whether the cost and delay calculation provided in this report produce values (for delay and cost) that approach the values that exist in reality. Validation of the model outcomes through comparison with a historic dataset won’t be possible, simply because that dataset is nonexistent. Delays are measured in the port, but not for every player in the game nor in a way that delays can be assigned as a result of certain actions. Cost that parties experience are not made public either. Even if such data was available, the way GSMs conceive of a problem would make it impossible to validate all outcomes. GSMs conceive a problem situation as a sort of an extended bargaining game, meaning that all players know what could happen (all players are familiar with the possible outcomes of a game), but only a select number of things do happen. The outcomes in the model could be compared to scenarios. A scenario could never occur, but it is a possible outcome. The difficulty in validation of scenarios is that these scenarios or outcomes might never happen but are in everyone’s awareness. That awareness includes a valuation of the outcome.

The validity of the outcomes is therefore derived from the assumptions underlying the calculation. If these seem reasonable (to experts), the outcomes can be considered valid. The assumptions made for the delay calculation among else determine who can(not) experience time gains, and how delays are assigned if several players act unreliably. These assumptions have been checked with several people in the Port Authority and are fully outlined in appendix B.

The cost calculations meanwhile have been put together with data gathered by the Port Authority, publicly available data and in one case the data came directly from a shipping company. The most important assumption in these calculations is that the delay cost of a player are assumed to be equal to the opportunity cost. This could lead to a systematic overestimation of delay cost. The delay cost are however not used for exact predictions, but more used for comparison between parties. Interviewees from the Tugboat Company Kotug and the pilot association agree with this assumption and the resulting approximations. The large difference between the cost that players charge others for caused delays and the experienced cost for a delay shown by the model is also something they can relate to. Finally, the sensitivity analysis done on both delay and cost parameters revealed that the margin for error is quite large. The findings where robust to large parameter changes.

In summary; the most relevant players are included in the game and those that are not included will likely not have a big influence on the conclusions. Furthermore the order of play is based on a formalised process. The assumptions about information and actions meanwhile are validated by experts. The outcomes to which these actions lead have face validity. The cost parameters are based on data from the Port Authority. The above leads to the conclusion that the game is an accurate enough representation of the departure order process.

7.4 ANALYSIS OF OUTCOMES

This paragraph will describe whether the conclusions set out in chapter 6 about the incentives of player logically follow from the outcomes of the game. To steer the analysis in chapter 6, paragraph 4.1.1 formulates five strategic hypotheses on the incentives of players to test. These hypotheses are based on interviews with several chain parties, and the data analysis in chapter 2. To test these hypotheses, all possible combinations of actions and
input variables are simulated. That results in a theoretical solution space in which the frequency of a certain outcome does not say anything about its probability in reality. The expected value of an action (and thereby the conclusions on the incentives of players) are however dependent on the expected value of an action. Whenever the conclusions hinges on the expected value of an action, expert opinions are used to say something about the probability of an outcome. The expected value of an action is also determined by the outcome of future games. As explained, games are not dynamically linked. By not linking games, the outcome of future games cannot be expressed by the model. It is taken into account in a qualitative sense in the analysis chapter though (see for example paragraph 6.1 and 6.2).

The conclusions are also dependent on how players value cost and delay. The utility that each players realizes for a particular delay and cost is called a payoff. In GSMs the assumption is that players choices are driven by the payoffs they expect to achieve. These payoffs are only relevant in case a player has to make a trade-off between cost and delay. The findings for the shipping company are the only ones that hinge on that ranking of values. That ranking of values was validated with the help of an expert from the Port Authority (see paragraph 6.2).

Ultimately, four of the five strategic hypotheses are supported by the findings. To clarify, only the strategic hypothesis related that stated that shipping companies with smaller ship sizes don’t have an incentive to communicate unreliably is falsified. The conclusions are found to be true in a wide variety of games, no matter the input variables. The findings are also robust for cost parameter changes and for changes in the time scale of actions. As such the conclusions have construct validity.

7.5 BEHAVIOUR IN REALITY

This paragraph will discuss whether the model can be deemed internally valid. That means that the behaviour shown in the model can be generalised to reality. Players in the game are assumed to act rationally and solely in the interest of the delay and cost they experience. Whether players act like this is very difficult to prove in the context of cooperating parties in a supply chain. A player would have to blatantly admit the he acts strategically for his self-interest, no matter the damage for other players. This is of course a sensitive issue. Furthermore one could wonder whether the people who make the decisions are aware of the relation between their actions and the outcomes that can be achieved and act rational given this knowledge. Nevertheless, this paragraph attempts to make the internal validity of the model believable.

The behaviour of the players in the model is explained by their valuation of cost and delay experienced as a result of an action. There are other factors that could be a plausible explanation for behaviour, that are not included in the model. In fact the games are quite naive in the sense that every game is an equal playing field. While, as discussed in paragraph 2.2, in reality parties sometimes favour their big clients in planning. The behavioural dynamics shown between players and their regular customers are not shown by the model. Neither does it show the influence of the human experience of delays on behaviour. Service providers could get ‘fed up’, with waiting for a player that is delayed and as a result act irrational (e.g. leave to service another ship) as far as cost and delay are concerned. So while the sensitivity analysis showed that the findings were not sensitivity to increasing the scale at which actions are taken (30 minutes versus 1 hour decision increments), people ‘on the ground’ might experience that differently.

The interviews with experts and particularly the experiences gained through an excursion with a pilot make clear that there is a fair amount of ‘wheeling and dealing’ between parties. The times coordinated in the ship handling process are human estimations based on experience and rounded off for convenience. Parties know not to take
these times at face value, to some extent. Trust between parties plays a role. A representative of the Pilot association explains that their planning department knows how to cope with delays. ‘If three departures are planned from the Europort, we expect at least one to be delayed and create buffers in the planning’ (Jan Kramer, personal communicated, August 24, 2015). The system shows adaptive behaviour to games that are played. The ‘softer’ variables that show up in practice are not represented in the model.

At the same time the model calculates ‘hard’ cost and delays. This gives to some extent insight in what is gained and lost, but clearly does not paint the whole picture. In reality the cost and delay might be lower because of the adaptive behaviour of players. However the conclusions are shown to be insensitive to parameter changes, thus these overestimations should not matter.

The question remains if these parties act in a rational way according to cost and delay. The above makes clear that these values are not the only values that these parties care about. However it is entirely believable that these parties will consistently pursue certain goals. It is not a big leap of faith to believe that cost and delay are the most important factors to these parties, given the nature of these parties (private businesses). It seems reasonable to say that in most cases cost and delay as expressed in the model explains the behaviour of players. An interviewed representative of a tugboat company agrees; “I am hundred percent convinced that some of these parties act according to these incentives” (Edwin van der Poel, personal communication, Augustus 17, 2015). Similarly the results are supported in that aspect by an expert from the Pilot association (Jan Kramer, August 24, 2015) and by an expert from the Port Authority (Ben van Scherpenzeel, July 27, 2015). At the very least the model has face validity.

7.6 CONCLUSION AND MODEL USE

With the validity of the model discussed, what can be concluded about its expressive power? Are the aspects of the departure order process that are not modelled, consequential? The validation of the model and its conclusions have been split up in three parts. The game itself can be seen as an accurate representations of reality. It shows a variety of situations, and takes into account that the departure order process is influenced by the rest of the ship handling process. The building blocks of the game are all validated by experts or based on data from the Port Authority. Moreover the outcomes have face validity. Secondly, the conclusions that follow from the game are robust for large parameter changes and confirm most of the strategic hypotheses formulated earlier. The conclusions have construct validity. Regarding the internal validity of the model, the previous paragraph argued that there are definitely variables and behaviour that cannot be explained by the model. In particular ‘softer’ variables such as trust or parties favouring regular clients are not included in the model. At the same time it is entirely believable that these parties will consistently pursue mostly low cost and delay. It seems reasonable to say that in most cases cost and delay as expressed in the model explain the behaviour of the players. There are several experts who support this believe.

Despite that it may seem like a good implementation of what is happening in the port, the model can never be proven. This document presents a case that is apparently valid to such an extent that it creates commitment to action. Providing a well-argued case that (the potential for) strategic behaviour is present creates a platform for dialog and allows for (pre-emptive) countermeasures. This clearly has value, given the implications of the modelled behaviour.

More content related the model can provide an explanation for why the terminal and shipping company will communicate unreliably (and other player won’t). This serves as an explanation for unreliable ETDs of departure orders and the high number of delay registered for these parties. It also explains why this problem is persistent. First of all the
findings are robust for large parameter changes. This implies that changes in delay penalties or terminal handling charges for example will not change the incentives of players. Next to that, the findings are robust for supply chain effects (the input variables described). This means that the ship handling system does not ‘correct’ itself (i.e. terminals won’t behave differently if there is a capacity arrangement). Thirdly, the resulting outcome for the port is a pareto optimal outcome. Pareto optimal means that no player can benefit from a move change, without another player getting worse of. This means that changing behaviour is difficult to achieve with actions of player within the current game. Finally, because the model can show that the delay cost for terminals is several orders of magnitude higher than that of every other player. This last point also provides insight in what value (approximately) is won by players by acting a certain way, and also what value has to be compensated in some way to change behaviour (which is helpful for policy measures).
8 CHANGING THE GAME

The previous chapter concludes that the model can provide an explanation for why the terminal and shipping company will communicate unreliably (and other player won’t). This serves as an explanation for unreliable ETDs of departure orders and the high number of delay registered for these parties. This chapter depict what can be done by the Port Authority and other parties to increase to reliability of ETDs. This entails implementing policy measure to change the inferred behaviour of the terminal and shipping company. The three intervention ‘avenues’, set out in paragraph 4.1.2, will be explored. The first paragraph describes the possibilities intervene in the departure order game with moves. The next paragraph discusses value sharing interventions. Interventions on the information element in the game are described thereafter. After that, the most promising policy measure are put forward as recommendations. How these recommendation relate to each other is discussed as well. The chapter concludes with a paragraph on further research possibilities and a paragraph on lessons that are learned from this thesis.

8.1 CHANGE OF MOVES

As explained in chapter 6, the incentives of the different players lead to a system outcomes that is a pareto optimum. This means that no player can benefit from a move change, without another player getting worse of. Any consistent move change of player will be experienced by other players, who subsequently can counteract that move. Hence remedying coordination failure is difficult with moves in this game. To illustrate; pilots and tugboats could as a reaction to unreliable ETDs respond late to departure order to achieve more preferable outcomes for themselves. However a terminal could counteract that move change by communicating an even earlier end of operations time.

There are Kaldor-Hicks efficient outcomes to be found though, namely outcomes in which the terminal and the shipping company communicate reliably. These are outcomes which have a lower total system cost and total system delay (sum of cost and delay of all players) than the outcomes in which the players act according to their incentives. Hypothetically the extra value that is earned by moving to this outcome could be used to compensate the players that experience damage from that move. A Pareto-improvement is then achieved (i.e. no player worse off). This implies that reallocation of value could be a viable policy measure. Furthermore the model provides insight in how much value has to be approximately compensated to a player to warrant a change in behaviour.

8.2 CHANGE OF VALUE SHARING

In order to come up with policy measures based in value reallocation three question need to be answered. The first is ‘What is the value created by a change in outcome?’. The second is ‘What is the value that needs to be reallocated to change the behaviour of the players. Finally thoughts need to be given about the form of the policy measure.

Table 14 shows the cost (rounded) and delay for every player in a situation in which the terminal and shipping company both communicate a departure time 30 minutes earlier than they perceive to be true. The ship in question has a capacity of 1500 TEU. The cost for the terminal are zero because the terminal does not cause delay for the shipping company. The shipping company meanwhile needs to compensate the NSP in accordance with the chargeable rates. By moving to the ‘reliable’ outcome, €2060 is created and the delays for the players other than the terminal and shipping company are reduced to 0. Note that the Pilots and Shipping companies benefit the most in terms of cost, from the switch in behaviour.
The table does not adequately show the reasoning that could go behind a terminal and shipping company communicating unreliably. By communicating as such, the chance of experiencing delays is reduced and the chance of the terminal operations finishing earlier than expected is increased. The hourly delay cost of a terminal and shipping company meanwhile are €14500 (rounded) and €3500 respectively. The incentive for a terminal to act unreliable would switch to acting reliable if either the damage of experiencing a delay is compensated (both in time and cost) or the chance of it happening are decreased sufficiently. The shipping company however mainly cares about minimizing its port stay time, financial compensation would have to be a lot higher than €3500 to negate a delay.

Given the large gap in value created and value needed to change behaviour it is seems that a policy measure aiming to fully compensate the damage that the terminal and shipping company experience in case of a delay with financial incentive would cost more than it delivers. Also note increasing the cost that NSP charge for delays caused by the shipping company is unlikely to have the desired effect. The difference between the delay cost per hour for a shipping company and the charged costs are simply too large for that. Besides that, client-customer relations might suffer from implementing such a measure.

Seeing as there is not enough value created by a switch in behaviour to completely compensate the delay cost of the terminal and shipping company, other values that these parties have can perhaps be utilised in an intervention. Examples of such values are prestige or perception of trustworthiness. These values help these parties in finding new clientele. A possible policy measure that could attribute to this is naming and faming container terminal or shipping companies as ´the most reliable´. This title can be complemented with a financial reward. It would benefit the port as a whole the most if this title is awarded to the companies that register the lowest ratio of delay per ship departure. Both the number of departures and delays are registered by the Port Authority, so the instruments are in place to rank container terminal and shipping companies. However, the financial means to implement such a measure effectively might lie with the Port of Rotterdam PLC. Discounts on land leases and port dues can be thought of as instruments. Other parties can also be asked to contribute, as they also benefit from the expected change in behaviour (especially pilots, as shown by table 14). Estimating an effective height of the financial reward is beyond the scope of this report.

Table 14: Creation of value by changing behaviour

<table>
<thead>
<tr>
<th>Players</th>
<th>Situation</th>
<th>Variable</th>
<th>Terminal</th>
<th>Shipping Company</th>
<th>Shipping Agent</th>
<th>Port Authority</th>
<th>Pilot</th>
<th>Tugboat Company</th>
<th>Boatmen</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unreliable</td>
<td>ETD</td>
<td>Delay</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cost</td>
<td>0</td>
<td>700</td>
<td>150</td>
<td>300</td>
<td>800</td>
<td>40</td>
<td>70</td>
<td>2060</td>
</tr>
<tr>
<td>Reliable</td>
<td>ETD</td>
<td>Delay</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cost</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Value created</td>
<td></td>
<td>Delay</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cost</td>
<td>0</td>
<td>700</td>
<td>150</td>
<td>300</td>
<td>800</td>
<td>40</td>
<td>70</td>
<td>2060</td>
</tr>
</tbody>
</table>

A second way of changing the behaviour of terminals and shipping companies through value sharing is by reducing the chance of delays. The delay data registration in paragraph 2.3 shows that 29% of delayed container ship departures can be attributed to NSP not being on time. Meanwhile, the formal chart (figure 11) in paragraph 2.5.2 shows that tugboat companies are in competition with each other. This means that tugboat companies are under pressure to maximise their utilisation of resources to guarantee market-conform prices. The Pilot association experiences similar pressure from the ACM (Authority for Consumers & Markets), which requires efficiency improvements from the
Pilot association every year. In this context, it is apparently unprofitable for the NSP to invest in extra capacity. The point of this thesis of course, is that terminals and shipping companies always have an incentive to act strategically, if there is a chance of delay. Even if they know that there is not enough capacity.

In this context it would makes sense for the Port Authority (and other parties) to subsidize the NSP to invest in otherwise unprofitable capacity. That could equally mean investing in new tugboats, extra planners, or more pilots. To identify the most effective investment, future research is needed into the bottlenecks of the NSP. Acquiring such investments is highly desirable for the different NSP. Hence, such future research is best be carried out by an independent party. Convincing other parties of the need of this policy measure might also prove difficult. Because ‘why should other players invest to prevent delays caused by the terminal and shipping company?’ That rhetoric can be countered by pointing at the ineffectiveness of that attitude and at the potential benefits of the measure (i.e. lower cost and delay for all involved parties). Ultimately it might be more cost-efficient to subsidize surplus capacity of the NSP rather than to invest in difficult value sharing schemes or information sharing systems.

8.3 CHANGE OF INFORMATION

Coordination problems are often addressed by sharing information between parties (e.g. the Pronto project). As explained in paragraph 4.1, given the resistance to these initiatives it would be interesting to investigate where (between which players) information sharing would have the biggest effect (in reducing delays and cost in the system). The model can shed some light on that.

The influence that a player can have on the total delay and total delay cost in the model is shown by table 16. The sum of the system delay and system cost associated with the actions each players can make are described there. The range of the achieved cost and delay then say something about the theoretical influence a player has. In this case the terminal and shipping company show the biggest range in terms of delay and cost. The NSP are a close second with regard to influence on delay. Having the biggest range and exercising the most influence are two different thing though. The findings from chapter 6 support the notion that the terminal and shipping make the most use of their influence.

To further elaborate on the effect of information sharing, we must consider what the effect is of an information sharing measure in game theoretical terms. Paragraph 4.5.1 characterises the departure order process as a game with imperfect information. A player does not know what the previous players has done, until the player himself has acted. Information sharing then entails that two or more parties have the same availability of information. At least if information sharing is done truthfully. In this game that could mean that player 2 and 3 share the information they receive from player 1. Now both player 2 and 3 know that player 1 has communicated a time of 15:00 (for example). That is NOT the same as telling a certain player where he is on the decision tree. That would instead mean that a player knows ALL precious decisions taken. A piecewise unlocking of information however implies that player only know decisions made by one other party.

The options of the game consist of manipulating the information received, before communicating it to the next player. That manipulation would become impossible for the player, without the other player noticing it. In reality, if player 3 would notice that player 2 has manipulated the information unfairly (e.g. order early with the intent of creating a desirable outcome), player 3 could of course counteract that effort and nullify its effect (or not if it is desirable). Hence the option space is reduced to 1 option (see figure 28 and 29). Communicating what has been communicated previously (or change and inform).
Table 15: Influence of players on system

<table>
<thead>
<tr>
<th></th>
<th>Decision -0.5</th>
<th>Decision 0</th>
<th>Decision 0.5</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal</td>
<td>600</td>
<td>900</td>
<td>1200</td>
<td>600</td>
</tr>
<tr>
<td>Shipping company</td>
<td>600</td>
<td>900</td>
<td>1200</td>
<td>600</td>
</tr>
<tr>
<td>Shipping Agent</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>0</td>
</tr>
<tr>
<td>Port Authority</td>
<td>1300</td>
<td>1400</td>
<td>1400</td>
<td>100</td>
</tr>
<tr>
<td>Pilot</td>
<td>1300</td>
<td>1400</td>
<td>1400</td>
<td>100</td>
</tr>
<tr>
<td>Tugboat-company</td>
<td>1300</td>
<td>1400</td>
<td>1400</td>
<td>100</td>
</tr>
<tr>
<td>Pilot response</td>
<td>1100</td>
<td>1600</td>
<td>1600</td>
<td>500</td>
</tr>
<tr>
<td>Tugboat-response</td>
<td>1100</td>
<td>1600</td>
<td>1600</td>
<td>500</td>
</tr>
</tbody>
</table>

Influence of players on total system cost [x 1,000,000 €]

<table>
<thead>
<tr>
<th></th>
<th>Terminal 3.6</th>
<th>Terminal 6.4</th>
<th>Terminal 9.2</th>
<th>Terminal 5.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipping company</td>
<td>3.6</td>
<td>6.4</td>
<td>9.2</td>
<td>5.6</td>
</tr>
<tr>
<td>Shipping Agent</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>0</td>
</tr>
<tr>
<td>Port Authority</td>
<td>9.0</td>
<td>10</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Pilot</td>
<td>9.0</td>
<td>10</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Tugboat-company</td>
<td>9.0</td>
<td>10</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Pilot response</td>
<td>8.4</td>
<td>10.8</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>Tugboat-response</td>
<td>8.4</td>
<td>10.8</td>
<td>2.4</td>
<td></td>
</tr>
</tbody>
</table>

Figure 28: Game tree with incomplete information

Figure 29: Game tree with information sharing
So if information sharing reduces the option space of players, the most effective information sharing measures are those that focus on reducing the options space of the players with the largest and used influence range. That are the terminal and the shipping company. The model does not allow for useful statements on how large the effect of information sharing may be in reality. That would for example require knowing which part of the delays caused by terminal is due to strategic behaviour based on incentives and which part is due to other factors, not taken into account in the model. Another reason is that players might for example react to the intervention, changing their past behaviour.

Now that it is made clear where (between which players) information sharing would have the biggest effect, the question is how such a scheme would practically be implemented. For a terminal and shipping company to share information in the manner as described above, would mean that the shipping company can determine how realistic the communicated end of ops time is. That implies a transparent berth planning, giving the shipping company real-time insight in the handling process of their ship. Providing historical statistics to the shipping companies could be a less invasive and less expensive way to share information. “For each vessel calling at the terminal, the vessel turn-around time at the port can normally be calculated by examining historical statistics (number of containers handled for the vessel, the crane intensity allocated to the vessel, historical crane rate, etc.) [Dai, Lin, Moorthy, & Teo, 2008]”. The feasibility of terminals sharing that information is unclear. Alternatively, shipping companies that frequently visit the Port of Rotterdam could register these statistics on their own accord.

For a shipping company to share information in the manner as described earlier, would mean that the agent can determine how realistic the desired ETD is. That implies that the end of cargo operations time of the terminal is communicated to both the shipping company and the shipping agent. It is already presumed that the shipping company and agent share that information, but that the agent is not inclined to stray from the wishes of his client. Hence the agent is modelled as a pseudo player in the game. To reduce the option space of the shipping company, the information the shipping company and agent receive from the terminal needs to be shared with the Port Authority. A possibility for that is the departure order that agents send to the Port Authority. If the departure is expanded with the End of cargo operations time they receive from the terminal, the ETD cannot be set at an unrealistic time by the shipping company. It is within the competences of the Port Authority to set new requirements for the departure order. Although this does mean that shipping agents will have to spend more time on the departure order.

The Pronto project (see paragraph 1.1.1) envisions that the end of cargo operations time is shared with all chain parties through a special application software. The findings in this report thus support that aspect of the Pronto project. However, the Pronto project is a lot more comprehensive in the parties it includes and the information it requires. This paragraph pinpoints to the information that has the most effect (according to the model), if shared. Moreover the game theoretic characterisation of information explains why it would work. Should Pronto not be implemented, for whatever reason, the proposal described above can be used as an alternative. The ETD could also be included in the departure order temporarily, during the transition to Pronto.

### 8.4 PROPOSED MEASURES

This chapter discussed some policy measures the Port Authority could undertake to decrease unreliable ETD’s and thereby delays and costs in ship handling. The recommended measure are summarised briefly in this paragraph. They are presented in decreasing order of actionability for the Port Authority.
**Recommendation 1:** Expand the departure order to include the ‘end of cargo operations time’ that shipping agents receive from terminals.

This proposal is the most actionable measure because it falls within the Port Authority’s competences to set requirements for the departure order and there is little investment needed from the Port Authority’s side. The recommendation can be perceived as a supportive argument for the Pronto initiative. However, Pronto and expanding the departure are not similar. Instead, the departure order can be expanded temporarily, during a transition to Pronto.

**Recommendation 2:** Introduce a ‘most reliable terminal and shipping company of the year’ title, including financial incentive.

The aim of the first proposal is to change the behaviour of shipping companies that act unreliably. The model however showed that terminal equally have an incentive to communicate unreliably (see paragraph 6.1). By naming, faming and rewarding the most reliable terminal and shipping company an incentive is created for these parties to communicate reliable. It benefits the chain parties the most if this title is awarded to the companies that register the lowest ratio of delay per ship departure. The award is actionable for the Port Authority, because both delays and number of ship departure are registered on the level of individual companies. Determining an effective height of the financial reward is beyond the scope of this research though and could be subject to further research.

**Recommendation 3:** Subsidize unprofitable capacity of Nautical Service Providers

The second recommendation will likely not affect the behaviour of all terminals and shipping companies. Namely, because winning the award is an uncertain payoff. Meanwhile, the findings from the model show that cargo terminals and shipping companies always have an incentive to communicate strategically to reduce the chance that they are delayed. This chance of delay partly exist because NSPs have economic drivers to maximise the amount of vessels they can service with their resources. In that context some investments in capacity are unprofitable. Subsidizing this otherwise unprofitable capacity would reduce the chance of delay and thereby remove the incentive to communicate unreliably. To identify the most effective investment, future research is needed into the bottlenecks of the NSP. Such future research is best be carried out by an independent party.

This chapter also led to the identification of two recommendation for other players. Firstly, all chain parties benefit if the measure described above are implemented. Thereby the recommendation is that these parties contribute to them. The second recommendation is directed to the terminal and shipping company. Paragraph 8.3 explains that the departure order can be made more reliable by making berth planning transparent to shipping companies. However, the feasibility of terminals sharing that information is unclear. Alternatively, shipping companies that frequently visit the Port of Rotterdam could register these statistics on their own accord.

### 8.5 FURTHER RESEARCH

This paragraph will discuss the opportunities for future research that have been identified throughout this report. These opportunities can be splits up into two groups: future research that strengthens this thesis or that is to the benefit of the Port of Rotterdam, and research that could be of interest to the academic community.
The findings in this thesis can be made more robust through a couple of researches. The first is adding stochastic variables in the simulation model to test the strategic hypotheses further. One example would be a stochastic end of operations time (as explained in paragraph 7.3). Another addition to the simulation model would be to add smaller ship sizes. Potentially strategic hypothesis 3 could be supported with this modification. Thirdly, the validity of the cost parameters can be researched further. New research could check them with more parties then is done currently. Meanwhile, a quite comprehensive study would be to dynamically link games. By not linking games, the outcome of future games cannot be expressed by the model. It is taken into account in a qualitative sense in the analysis chapter though. Paragraph 4.2 provides insight in what linking games would entail. Lastly, two of the recommendation done in the previous paragraph require additional research. See the previous paragraph for more information.

Paragraph 2.7 set the scope of this thesis on the departure order. However, other delay related problems that can be further researched with a similar research approach. Appendix D identifies other parts of the ship handling process that were candidates for the scope of this thesis.

This thesis has shown the use of a GSM application in the Port of Rotterdam. It would be interesting see if a GSM application in other ports would lead to similar results. Similarly, a GSM application in a different kind of supply chain could also be of interest for academic purposes. Chapter 10 discusses opportunities for generalizable findings.

8.6 LESSONS LEARNED

The value of the research approach is not solely in the recommendations described in this chapter. The thesis led to a number of insight about the behaviour and incentives of players in the departure order process. Some of these findings support the recommendations, other explain why other policy measures will likely not work. The most important lessons are described here.

Most importantly, the model can provide an explanation for why the terminal and shipping company will communicate unreliably (and other player won’t). This serves as an explanation for unreliable ETDs of departure orders and the high number of delay registered for these parties. It also explains why this problem is persistent (see paragraph 7.6).

Furthermore, by estimating the cost associated to delays per individual player mainly provides insights what policy measures will be ineffective. For example, it shows that there is a gap between the value created if the terminal and shipping company change their behaviour and the value needed to achieve with direct financial compensation. Expressing the delay cost per hour per players also shows that increasing the cost that NSP charge for delays caused by the shipping company is unlikely to have the desired effect. The difference between the delay cost per hour for a shipping company and the charged costs are simply too large for that. The cost parameters that have been specified for the model (see appendix F) can potentially be used in other delay related question in the Port of Rotterdam. Similarly, some principles from the mathematical model used to calculate delays for every player in the game can perhaps be used to expand the delay registration.
CONCLUSIONS AND RECOMMENDATIONS

The analysis of the delay registration and conceptualisation of the ship handling system showed that the departure order process had the biggest relevance for further investigation. The main research question was accordingly adjusted to:

**To what extent can incentives based in delay and cost of individual chain partners in ship handling explain delays in the departure process of sea-going container vessels in the port of Rotterdam?**

This main research question is split out into the following sub-questions.

1. How do chain-parties coordinate and where does this coordination fail?
   a. Who are the players?
   b. Which actions do they have?
   c. In what order do these actions take place?
   d. What is the information that these players have?
   e. What are the outcomes to which parties are driven by their payoffs?
   f. Do these outcomes serve as an explanation for an unreliable ETD?

2. Can the identified coordination failure be validated?
   a. Is there evidence to support the outcome?
   b. Do chain partners deem the outcome probable?

A game structuring method based analysis was carried out to answer these questions. More specifically, a ‘metagame’ analysis framework was seen to fit well with the problem situation. To steer that analysis somewhat, five strategic hypothesis about the behaviour of different ship handling parties were formulated. These hypotheses are based on interviews with experts from several chain parties. Moreover, if all hypothesis are supported they provide an explanation for unreliable ETDs and thereby delays in ship handling.

The following strategic hypotheses are used:

- **Strategic hypothesis 1:** Container terminals have an incentive (expressed in time and money) to communicate an expected end-of-ops-time that is a low estimate of the end-of-ops-time they actually perceive to be true (i.e. communicate an unreliable ETD).
- **Strategic hypothesis 2:** Shipping companies have an incentive (expressed in time and money) to communicate an estimated time of departure that is lower than the ETD they actually perceive to be true (i.e. communicate an unreliable ETD).
- **Strategic hypothesis 3:** Shipping companies with smaller ships don’t have an incentive (expressed in time and money) to communicate an estimated time of departure that is lower than the ETD they actually perceive to be true (i.e. communicate an unreliable ETD).
- **Strategic hypothesis 4:** Other parties experience damage from unreliable departure orders, but their financial damages are relatively low. The incentive to counteract unreliable departure orders is thereby existent, but small.
- **Strategic hypothesis 5:** These incentives lead to unreliable departure orders, which result in Pareto optimal outcomes.

Subsequently the departure order process has been framed in the form a ‘game’, meaning simplification to the key coordination decision moments of the involved parties. The answers to the first set of sub-questions (1a – 1e) are essentially the building block of that game.
The players in the game are; terminal, shipping company, shipping agent, port authority, pilot, tugboat company and boatmen. In this game the decisions available to the player in the game consist of manipulating the expected departure time (or not), before communicating that time to the next player in the process. The players act in the same order as they are listed above. Meanwhile information in the game is imperfect. This means that players do not know what the other player has done for certain, until after the player himself has acted. Because of these characteristics players can potentially communicate a time that they know not to be realistic, in the hope that other players act upon that time. The question is whether acting as such lead to better results for the player than if he does not manipulate the departure time.

The effects of actions on both the delay and cost players experience can be calculated with the mathematical models specified in chapter 4. To then generate the outcomes that are required for testing the strategic hypotheses, both mathematical models (for cost and delay) have been translated into a simulation model.

The answer of sub-question 1e and 1f is best described through the findings for the strategic hypotheses. The analysis of the simulation outcomes showed that strategic hypothesis 1, 4, 5 were supported, while strategic hypothesis 2 and 3 were strictly speaking falsified. More specifically, container terminals have an incentive to communicate an unreliable ETD. For shipping companies there is no incentive in time AND delay to communicate an unrealistic ETD. However, the model does shows that the ‘best’ way for a shipping company to minimize the port stay time of a ship is to communicate unreliable. Moreover, the outcomes do not show that a shipping company has an incentive to act differently if it regards a 1500 TEU ship compared to when it regards a 16000 TEU ship. For the Port Authority, Pilot and Tugboat company, there is a small portion of outcomes that provide better results if they would set a later ETD. The benefit of acting as such is however small and in most outcomes leads to much higher costs. These parties thus indeed have a small incentive to counteract unreliable departure order, but are not likely to act upon this incentive. The inferred incentives of the above players will result in an unreliable departure order. Furthermore this leads to a Pareto optimal outcome. This means that no player can benefit from a move change, without at least one player getting worse off. This has implications for the policy measures.

The second set of sub-question regard the validation of the model and its conclusions. This has been split up in three parts. The game itself can be seen as an accurate representations of reality. It shows a variety of situations, and takes into account that the departure order process is influenced by the rest of the ship handling process. The building blocks of the game are all validated by experts or based on data from the Port Authority. Secondly, the conclusions that follow from the game are robust for large parameter changes and confirm most of the strategic hypotheses formulated earlier. Regarding the internal validity of the model, there are definitely variables and behaviour that cannot be explained by the model. At the same time it is entirely believable that these parties will consistently pursue mostly low cost and delay. Therefor it seems reasonable to say that in most cases cost and delay as expressed in the model explain the behaviour of the players. There are several experts who support this believe.

Returning to the main research question, the model can provide an explanation for why the terminal and shipping company will communicate unreliably (and other player won’t). This serves as an explanation for unreliable ETDs of departure orders and the high number of delay registered for these parties. It also explains why this problem is persistent (see paragraph 7.6).

The research also provides insight into what can be done by the Port Authority to decrease unreliable ETD’s and thereby delays and costs in ship handling. The following measures are recommended (in order of most actionable, to least actionable).
• Expand the departure order to include the ‘end of cargo operations time’ that shipping agents receive from terminals
• Introduce a ‘most reliable terminal and shipping company of the year’ title, including financial incentive.
• Subsidize unprofitable capacity of Nautical Service Providers.

The first recommendation can be perceived as a supportive argument for the Pronto initiative. However, Pronto and expanding the departure are not similar. Instead, the departure order can be expanded temporarily, during a transition to Pronto.

By naming, faining and rewarding the most reliable terminal and shipping company an incentive is created communicate reliable. It benefits the chain parties the most if this title is awarded to the companies that register the lowest ratio of delay per ship departure.

Subsidizing this otherwise unprofitable capacity would reduce the chance of delay and thereby remove the incentive to communicate unreliably. To identify the most effective investment, future research is needed into the bottlenecks of the NSP.

This report also led to the identification of two recommendation for other players. Firstly, all chain parties benefit if the measure described above are implemented. Thereby the recommendation is that these parties contribute to them. The second recommendation is directed to the terminal and shipping company. The departure order can be made more reliable by making berth planning transparent to shipping companies. Alternatively, shipping companies that frequently visit the Port of Rotterdam could register cargo handling statistics on their own accord to achieve the same effect.
10 REFLECTION AND DISCUSSION

This paragraph discusses possibilities to generalise the findings in this report to other ports. A reflection on the use of GSMs is also included.

10.1 GENERALISABLE FINDINGS

The result of PSMs are often non-transferable because applications tend to focus on a specific complex problem [Ackermann, 2012]. A special issue on problem structuring research and practice in the EURO J Decision Process lists eight challenges to the PSM field and practice, one of which is “identifying generalisable model findings” [Ackermann et al., 2014]. Which raises the question to what extent the findings for the Port of Rotterdam can apply for other ports?

Other European port also will be motivated to decrease delay in ship handling, due to increased inter-port competition. These port however could have other causes for delay. The physical or geographical attributes of ports are not the same, but play a role in ship handling. For example the port of Hamburg has a very long and narrow run up to the berths, which means there is little manoeuvring room for ships to pass each other. The entry to the port of Antwerp meanwhile has a sluice. Both examples of bottlenecks that the Port of Rotterdam does not have. Organisational or actor network related factors could also explain difference in causes for delays. The Antwerp Port Authority for example owns the tugboat company.

However there could also be commonalities; Terminals are likely in every port the biggest contributor in terms of value created. Their investments are several orders of magnitudes higher than the investments of other parties. This will likely create similar dynamics. The robustness of the findings to parameter changes suggests that if the departure process of a containership is somewhat similar to the process in the port of Rotterdam, AND there are sometimes (i.e. there is a risk for) delays caused by the unavailability of NSP capacity, that terminals have an incentive (both in time and cost) to communicate unreliably in that process. The same goes for a shipping company. In other words, there seem to be opportunities for generalisability. Further research could point that out.

10.2 GAME STRUCTURING METHODS

The use of a metagame framework, combined with a simulation definitely seems to have value. Conversations with several stakeholders (both inside as outside the Port Authority) reflect genuine interest in the approach and agreement with the findings. However as a beginning user of these type of methods you are faced with a number of challenges. The scientific article that is part of the deliverables for this thesis explains what difficulties need to be overcome as a novice in the PSM practice. It offers guidance to other (novice) users by not only making these challenges concrete through referring to experiences that were gained in the process of writing this thesis, but also by describing how these challenges were dealt with.
REFERENCES


GS1 Denmark and GS1 Hungary. (n.d.). Port Call Optimization a Reliable Port starts with Reliable Information. (Unpublished company document).


Port of Rotterdam. (2015c). Port tariffs, discounts and general terms and conditions.


**APPENDIX A: MAIN AND SUB CATEGORIES OF DELAY**

<table>
<thead>
<tr>
<th>Hoofdcategorie</th>
<th>Subcategorie</th>
<th>Toelichting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nautische dienstverleners</td>
<td>Loodsen</td>
<td>Vertraging doordat de Loods zijn dienstverlening niet op tijd startte.</td>
</tr>
<tr>
<td></td>
<td>Sleepdiensten</td>
<td>Vertraging doordat de Sleepboot(en) de dienstverlening niet op tijd startte(n).</td>
</tr>
<tr>
<td></td>
<td>Roeiers</td>
<td>Vertraging doordat de Roeiers de dienstverlening niet op tijd startten.</td>
</tr>
<tr>
<td>Cargo services</td>
<td>Lading</td>
<td>Vertraging doordat de ladingactiviteiten nog niet zijn afgerond.</td>
</tr>
<tr>
<td></td>
<td>Documenten</td>
<td>Vertraging doordat de documenten nog niet in orde zijn.</td>
</tr>
<tr>
<td></td>
<td>Lading Inspectie</td>
<td>Vertraging doordat de inspectie van de lading niet tijdig afgerond was.</td>
</tr>
<tr>
<td></td>
<td>Draft Survey</td>
<td>Vertraging doordat draf survey nog niet is afgerond.</td>
</tr>
<tr>
<td></td>
<td>Ship to Ship</td>
<td>Vertraging doordat een vanwege STS operations langszijs liggend schip niet tijdig vertrokken was.</td>
</tr>
<tr>
<td></td>
<td>Lashings</td>
<td>Vertraging doordat het aanbrengen van lashings niet tijdig afgerond was.</td>
</tr>
<tr>
<td></td>
<td>Technische mankement</td>
<td>Vertraging doordat er technische problemen zijn op de terminal.</td>
</tr>
<tr>
<td></td>
<td>Overige services</td>
<td>Vertraging om andere redenen met betrekking tot ladinghandelingen.</td>
</tr>
<tr>
<td>Vessel services</td>
<td>Bunkerij</td>
<td>Vertraging doordat het bunkerproces nog niet is afgerond.</td>
</tr>
<tr>
<td></td>
<td>Reparaties</td>
<td>Vertraging doordat het reparatie werkzaamheden nog niet is afgerond.</td>
</tr>
<tr>
<td></td>
<td>Controle op verstekelingen</td>
<td>Vertraging door controle op verstekelingen</td>
</tr>
<tr>
<td></td>
<td>Sludge</td>
<td>Vertraging doordat de afgifte van sludge niet tijdig afgerond was.</td>
</tr>
<tr>
<td></td>
<td>Slops</td>
<td>Vertraging doordat de afgifte van slops niet tijdig afgerond was.</td>
</tr>
<tr>
<td></td>
<td>Technische mankement</td>
<td>Vertraging doordat er technische problemen met het schip zijn.</td>
</tr>
<tr>
<td></td>
<td>Vetting</td>
<td>Vertraging doordat Vetting inspectie nog niet is afgerond.</td>
</tr>
<tr>
<td></td>
<td>Overige services</td>
<td>Vertraging om andere redenen met betrekking tot vessel services.</td>
</tr>
<tr>
<td>Autoriteiten</td>
<td>Douane</td>
<td>Vertraging wegens douane-onderzoek.</td>
</tr>
<tr>
<td></td>
<td>Immigratie</td>
<td>Vertraging wegens immigratie-onderzoek.</td>
</tr>
<tr>
<td></td>
<td>Zeehavenpolitië</td>
<td>Vertraging wegens ZHP-onderzoek.</td>
</tr>
<tr>
<td></td>
<td>Overige</td>
<td>Vertraging wegens onderzoek door andere autoriteiten.</td>
</tr>
<tr>
<td></td>
<td>Inspectie</td>
<td>Vertraging doordat een inspectie door afdeling D/HMR/inspectie niet tijdig afgerond is.</td>
</tr>
<tr>
<td>Havenmeester</td>
<td>HCC</td>
<td>Vertraging doordat er verkeerd is ingepland op het HCC.</td>
</tr>
<tr>
<td></td>
<td>VA</td>
<td>Vertraging doordat VA het schip wegens bv. veiligheidsredenen niet laat vertrekken.</td>
</tr>
<tr>
<td></td>
<td>PVT</td>
<td>Vertraging doordat een patrouillevaartuig het schip niet laat vertrekken.</td>
</tr>
<tr>
<td></td>
<td>Restrictions</td>
<td>Vertraging doordat er vanuit de HMR bepaalde restrictions gelden, waardoor het schip niet kan vertrekken of binnenkomen.</td>
</tr>
<tr>
<td>Verkeersbeeld</td>
<td>Onbeschikbaarheid object storing</td>
<td>Vertraging doordat een brug of sluit (tijdelijk) niet beschikbaar is door een storing.</td>
</tr>
<tr>
<td>Stemming</td>
<td>Onbeschikbaarheid object onderhoud</td>
<td>Vertraging doordat een brug of sluit (tijdelijk) niet beschikbaar is door onderhoud</td>
</tr>
<tr>
<td></td>
<td>Incident</td>
<td>Vertraging door stemming van (een deel van) de vaarweg door een incident.</td>
</tr>
<tr>
<td></td>
<td>Evenementen</td>
<td>Vertraging door stemming van (een deel van) de vaarweg door een evenement.</td>
</tr>
<tr>
<td>Bezette ligplaats</td>
<td></td>
<td>Vertraging doordat de bestemmingskade bezet is.</td>
</tr>
<tr>
<td>Overig</td>
<td>Afbestelling</td>
<td>Alle oorzaken van vertraging die niet passen in bovengenoemde scenario’s.</td>
</tr>
<tr>
<td></td>
<td>Lading</td>
<td>Bij deze keuze altijd een toelichting geven.</td>
</tr>
<tr>
<td></td>
<td>Documenten</td>
<td>Alle oorzaken van vertraging die niet passen in bovengenoemde scenario’s.</td>
</tr>
<tr>
<td></td>
<td>Lading Inspectie</td>
<td>Bij deze keuze altijd een toelichting geven.</td>
</tr>
<tr>
<td></td>
<td>Draft Survey</td>
<td>Vertraging doordat draf survey nog niet is afgerond.</td>
</tr>
<tr>
<td></td>
<td>Ship to Ship</td>
<td>Vertraging doordat een vanwege STS operations langszijs liggend schip niet tijdig vertrokken was.</td>
</tr>
<tr>
<td></td>
<td>Lashings</td>
<td>Vertraging doordat het aanbrengen van lashings niet tijdig afgerond was.</td>
</tr>
<tr>
<td></td>
<td>Technische mankement</td>
<td>Vertraging doordat er technische problemen zijn op de terminal.</td>
</tr>
<tr>
<td></td>
<td>Overige services</td>
<td>Vertraging om andere redenen met betrekking tot ladinghandelingen.</td>
</tr>
</tbody>
</table>

*Figure 30: Sub-causes of delay*
### APPENDIX B: DELAY INFLUENCE TABLES

#### Figure 31: Delay influence diagram magnitude of delay

<table>
<thead>
<tr>
<th>Step in process</th>
<th>severity of delay</th>
<th>Shipping Company</th>
<th>Agency</th>
<th>Terminal</th>
<th>Vessel Services</th>
<th>Tugboat</th>
<th>Pilots</th>
<th>Port Authority</th>
<th>Boatmen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning phase</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>1 n.i.</td>
<td>n.i.</td>
<td>1 n.i.</td>
<td>1</td>
<td>1 n.i.</td>
</tr>
<tr>
<td>Sea passage</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>3 n.i.</td>
<td>n.i.</td>
<td>1</td>
<td>1 n.i.</td>
<td>1</td>
<td>1 n.i.</td>
</tr>
<tr>
<td>Gain arrival readiness and clearance</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>5 n.i.</td>
<td>3</td>
<td>2</td>
<td>2 n.i.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manoeuvering to berth</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>3 n.i.</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cargo and vessel operations</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>3 n.i.</td>
<td>n.i.</td>
<td>n.i.</td>
<td>n.i.</td>
<td>n.i.</td>
</tr>
<tr>
<td>Gain departure readiness and clearance</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Manoeuvering to sea</td>
<td>1</td>
<td>1</td>
<td>1 n.i.</td>
<td>n.i.</td>
<td>1</td>
<td>1</td>
<td>1 n.i.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Severity of delay caused by party

<table>
<thead>
<tr>
<th>Planning phase</th>
<th>46</th>
<th>38</th>
<th>78</th>
<th>24</th>
<th>34</th>
<th>20</th>
<th>21</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rescaled (1-5)</td>
<td>2.948717949</td>
<td>2.435897436</td>
<td>5</td>
<td>1.538461538</td>
<td>2.179487179</td>
<td>1.282051282</td>
<td>1.346153846</td>
<td>1</td>
</tr>
</tbody>
</table>

#### Figure 32: Delay influence diagram influence Port Authority

<table>
<thead>
<tr>
<th>Step in process</th>
<th>Influence of the port authority per party per step</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipping Company</td>
<td>Agency</td>
</tr>
<tr>
<td>Planning phase</td>
<td>1</td>
</tr>
<tr>
<td>Sea passage</td>
<td>3</td>
</tr>
<tr>
<td>Gain arrival readiness and clearance</td>
<td>4</td>
</tr>
<tr>
<td>Manoeuvering to berth</td>
<td>3</td>
</tr>
<tr>
<td>Cargo and vessel operations</td>
<td>5</td>
</tr>
<tr>
<td>Gain departure readiness and clearance</td>
<td>4</td>
</tr>
<tr>
<td>Manoeuvering to sea</td>
<td>3</td>
</tr>
</tbody>
</table>

Average influence per party

Average influence per party

<table>
<thead>
<tr>
<th>Planning phase</th>
<th>3,285714286</th>
<th>3,714286</th>
<th>2</th>
<th>3,25</th>
<th>3</th>
<th>5</th>
<th>3,333333333</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea passage</td>
<td>3,285714286</td>
<td>3,714286</td>
<td>2</td>
<td>3,25</td>
<td>3</td>
<td>5</td>
<td>3,333333333</td>
</tr>
<tr>
<td>Gain arrival readiness and clearance</td>
<td>3</td>
<td>3,714286</td>
<td>2</td>
<td>3,25</td>
<td>3</td>
<td>5</td>
<td>3,333333333</td>
</tr>
<tr>
<td>Manoeuvering to berth</td>
<td>3</td>
<td>3</td>
<td>3,714286</td>
<td>2</td>
<td>3,25</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

Rescaled

| Planning phase | 3,285714286 | 3,714286 | 2 | 3,25 | 3 | 5 | 3,333333333 |
| Sea passage    | 3,285714286 | 3,714286 | 2 | 3,25 | 3 | 5 | 3,333333333 |
| Gain arrival readiness and clearance | 3 | 3,714286 | 2 | 3,25 | 3 | 5 | 3,333333333 |
| Manoeuvering to berth | 3 | 3 | 3,714286 | 2 | 3,25 | 3 | 5 | 3,333333333 |
APPENDIX C: ACTIONS OF PLAYERS

STEPS IN DEPARTURE ORDER PROCESS

THE TERMINAL

The terminal has to communicate the end of ops time to the shipping company, so that they can make arrangements to clear the berth. “For each vessel calling at the terminal, the vessel turn-around time at the port can normally be calculated by examining historical statistics (number of containers handled for the vessel, the crane intensity allocated to the vessel, historical crane rate, etc.) [Dai et al., 2008].” Roughly said the end of ops time is the time at which all containers are loaded or offloaded to a ship. The estimation is done by a terminal employee, who among else takes into account the number of containers a crane can move from and to a ship per minute, the number of containers on a ship and the amount of cranes assigned to a ship and compares that with the mentioned historical statistics.

The end of ops time is dependent on a wide range of variables (whether the trucks that move the containers from the terminal are on time, defects in cranes, the productivity level of crane operators, etc). That leads to uncertainty in the end of ops time. The bandwidth of this uncertainty is unknown. Given the fact that terminals handle several hundred of ships a year and the fact that they want to optimise their berth utilisation, it is reasonable to assume that know to some extent the accuracy of their estimations.

Knowing the best possible estimation of the end of ops time does not necessarily mean that terminals will communicate that. What time they communicate influences, but not fully determines, the time the berth will be cleared by the ship. For a terminal it would be best if the time that it communicates clears the berth the fastest (due to coordination further along in the process), against the lowest cost (if potential delay penalties are outweighed by profit). This is not necessarily the best estimate available to them. Hence the choice terminals are faced with in the departure order game consist of communicating a low, best of high estimate of the end of operations time. On the basis of this decision the terminal has a perception of when the shipping company will order the NSP and when the ship can depart.

Possible actions:
- Low estimate of end of operations time
- Best estimate of end of operations time
- High estimate of end of operations time

Information:
Known: Actual end of operations time
Decision: Communicated end of operations time
Known: Perceived Arrival time of nautical service provider
Known: Perceived ETD

SHIPPING COMPANY

Having received an end of operations time, the shipping company now has to account for the time that is needed to prepare the departure of the ship. It takes nautical service provider some time to prepare a departure (lets first assume it takes 30 minutes. In reality the Pilot needs the most time, the tugboats and boatmen need less time). This preparation includes a pilot coming on board, discussing the unmooring manoeuvre, boatmen removing the lashings, coupling the tugboats and other things. Meanwhile
actual departure time is the actual EoOT plus the time needed for preparation. If the
nautical service providers are present before the EoOT the departure time moves closer
to the EoOT. Let’s also assume that the nautical service providers are usually order for
them to be present at the ship 15 minutes before the EoOT. Important to remember is
that the shipping company only has a perceived end of operations time that might differ
from the actual end of operations time (depending on what the terminal communicates).

Given the above, the shipping company has to communicate a desired arrival time
of nautical service providers to the agent, to let him make a departure request. Again the
time the shipping company communicates influences, but not fully determines, the time
the ship can depart. For a shipping company it would be best if the time that it
communicates lets the ship depart the fastest (due to coordination further along in the
process), against the lowest cost (if potential penalties are outweighed by profit). This is not
necessarily the perceived end of operations time plus 30 minutes. Hence the choice
shipping companies are faced with in the departure order game consist of communicating a
desired arrival time of nautical service provider relative to the perceived EoOT. On the
basis of this decision the shipping company has an expectation of when NSP will arrive and
when the ship can depart.

Possible actions:
- Desired arrival time NSP before estimate of end of operations time
- Desired arrival time NSP at estimate of end of operations time
- Desired arrival time NSP after estimate of end of operations time

Information:
Unknown: Actual end of operations time
Known: Perceived end of operations time
Decision: Desired arrival time of nautical service provider
Known: Perceived ETD

---

**SHIPPING AGENT**

Based on the information communicated by the shipping company a shipping agent sets up
a departure request and sends it to the Port Authority. This departure request consists of a
desired departure time, the desired arrival time of the NSP and includes information about
the ship, its cargo, the number of tugboats required, etc. The scope of the research only
includes the departure time. Given that the shipping company is the client of the agent it is
likely the agent will communicate the choice the shipping company made to the port
authority. The choices the shipping agents has are therefor similar to the shipping agent; it
regards communicating a desired arrival time of NSP relative to the perceived EoOT. The
desired departure time is derived is also communicated but can be derived from the
desired arrival time of NSP (+30 minutes). On the basis of this decision the shipping agent
has an expectation of when NSP will arrive and when the ship can depart.

Set up departure request
- Order before end of ops time
- At the end of ops time
- After end of ops time

Information:
Unknown: Actual end of operations time
PORT AUTHORITY

Having received the departure request from the shipping agent, the Port Authority determines whether the departure order can be carried in a safe manner or if it should delay the departure time. In both cases the order is communicated to the nautical service providers. As explained in the previous paragraph, in reality a great number of factors are taken into account when assessing the safety of a departure order. In this game however only the availability of the nautical service providers (whether a capacity arrangement is in effect) and the capacity of the waterways are considered. To clarify, the Port Authority decides on the order in which ships can pass each other, at point where capacity is limited. The main principle is ‘first come, first serve’ but additional criteria are used if the total flow of the shipping traffic can be improved and the accessibility of the Port has to be guaranteed.

Possible actions:
- Allow departure
- Allow departure later

Information:
- Unknown: Actual end of operations time
- Unknown: perceived end of operations time
- Known: Desired arrival time of nautical service provider
- Decision: Desired ETD

PILOT

Once the departure request has been received by the Pilot association, they will have to schedule a pilot to act on the order. Depending on the planning of the Pilot association the order has to be confirmed or amended. A feasible pilot on board time has to be communicated to the agent.

Possible actions:
- At requested time
- After requested time

Information:
- Unknown: Actual end of operations time
- Unknown: perceived end of operations time
- Known: Desired arrival time of nautical service provider
- Decision: Desired ETD

TUGBOAT COMPANY

Once the departure request has been received by the tugboat company, they will have to schedule a or multiple tugs to act on the order. Depending on the planning of the tugboat company the order has to be confirmed or amended. A feasible tugboat at berth time has to be communicated to the agent.
BOATMEN

Once the departure request has been received by the boatmen, they will have to schedule boatmen to act on the order. Depending on the planning of the boatmen order has to be confirmed or amended. A feasible boatmen at berth time has to be communicated to the agent. However since, the boatmen are a pseudo player, they only have the option to confirm the order.

Possible actions:
- At requested time

Information:
Unknown: Actual end of operations time
Unknown: perceived end of operations time
Known: Desired arrival time of nautical service provider
Decision: Desired ETD

PILOT

At this point the pilot association has communicated an expected pilot on board time. The question now is; what degrees of freedom does a pilot have in responding on a departure order? Earlier mentioned interviews show that there can be a difference in that what is communicated and how players act. This became apparent from the actions available to for example the terminal or the shipping company. Should a pilot respond to what turns out to be an unreliable ETD, the pilot experiences a delay. This delay could disrupt the schedule of the pilot association. A pilot could choose to try to prevent that from happening by reacting l to the departure order. When confronted with the question whether this option would be conceivable, Interviewees from the Pilots Association (Jan Kramer and Elco Oskam, personal communication) denied, saying the Pilot Law obligates pilots to respond on time. Indeed, article 15 of the Pilot Law (‘Loodsenwet’) states that pilots are obligated to service ships timely and non-discriminatory. Not abiding to this could result in a complaint at the disciplinary board, which can issue a warning, fine (max €2250), a suspension or limiting of a pilot’s authority. The fact that the law is quite specific about disciplinary action for not acting timely actually makes the action very conceivable (disregarding how undesirable it
would be for a pilot). Should the pilot decide to not respond on time, his perceived ETD is adjusted accordingly.

**Possible actions:**
- Respond on order time
- Respond later

**Information:**
- Unknown: Actual end of operations time
- Unknown: perceived end of operations time
- Known: Desired arrival time of nautical service provider
- Known: Perceived ETD
- Decision: Response time Pilots

---

**TUGBOAT COMPANY**

At this point the tugboat has communicated an expected tugboat at berth time. However, there can still be a difference in what is communicated and how players act. This is true for the Nautical Service Providers, as well as the other players. A tugboat still has the choice (disregarding at the moment how desirable it would be) to respond on the order on time or later. Should the tugboat decide to not respond on time, his perceived ETD is adjusted accordingly.

**Possible actions:**
- Respond on order time
- Respond later

**Information:**
- Unknown: Actual end of operations time
- Unknown: perceived end of operations time
- Known: Desired arrival time of nautical service provider
- Known: Perceived ETD
- Decision: Response time tugboats

---

**BOATMEN**

As said before, the boatmen will be a pseudo player in the game. Only one response to a departure order is available to them.

**Possible actions:**
- Respond on order time

**Information:**
- Unknown: Actual end of operations time
- Unknown: perceived end of operations time
- Known: Desired arrival time of nautical service provider
- Known: Perceived ETD
- Decision: Response time boatmen
What is the problem? The capacity of tugboats in the Port of Rotterdam has recently been put under pressure by longer shipping routes, an increased number of parties and a pending investigation of the Dutch competition authority which led tugboat companies to stop renting tugboats from their competitors during traffic peaks. There seems to be no indication of tugboat companies investing in new tugboats to address the issue. Due to the fact the companies are competing on cost, investments are likely difficult to earn back. These developments have made the capacity of tugboat services a bottleneck in the ship handling process. Solving this capacity problem is difficult for the Port Authority because it has no direct say over the resources that four private, competing tugboat companies spend.

Relevance: Several parties indicate (during interviews) that tugboat undercapacity is one the biggest causes of delay in ship handling. The delay registration supports this. It shows that nautical services are the second biggest cause of delay for containership that are departing (257 hours from September 1\textsuperscript{st} 2013 to February 25\textsuperscript{th} 2015). Note: The delays that are caused by tugboat companies for incoming ships are not registered.

Possible (sub)research questions:
- How big is the damage of undercapacity of tugs for other parties?
  - Does that exceed the investment needed for tugboats?
- What is the tugboat capacity that is desired, by whom?
- If increased capacity is desired: In what way can the increase be achieved? (for example by extra tugboats or providing different rendezvous locations or merging tugboat companies etc.)
In what way can tugboat companies be mobilised to increase their capacity?

**Involved parties:**
- Four tugboat companies
- Parties that experience effect of delays by tugboat companies; Shipping companies, Pilots, Shipping agents, Terminals, Boatmen, Vessel services

**Fits with Game structuring approach?** Game Structuring Methods are uniquely suited to deal with wicked problems. In wicked problems there is no agreement on the exact problem, cause or its solution. In that respect the problems regarding tugboat capacity cannot entirely be described as a wicked problem; its cause is not contested. Every party will agree that the too low tugboat capacity cause delays. What they do not agree upon is how they experience those delays (Shipping companies and terminal might experience them as very costly, while pilots can charge the shipping company for time spent waiting on a ship), or how it should be solved. Because of these characteristics GSMs can still be useful, despite the fact that the problem cannot be described as wicked. GSMs are suited to show and explain different perspectives at the same time. As such it could be used to show how tugboat capacity delays are experienced and should be solved according to the involved parties. More concretely, an application of GSM could be used to explain and show;

- Why tugboat companies are not interested in investing in extra capacity
- The potential benefits for different parties if investment in extra tugboat capacity is done
- How bad the delays of tugboat capacity would have to get before tugboat companies would invest (under the assumption of rationality).

**Risks of choosing this game for thesis:** One risk is that the investigation by ACM (competition authority) into the practice of tugboat companies could come to conclusion, dramatically changing the situation while writing the thesis. Another issue is that tugboat capacity problems are not confined to a single (ship handling) process step, creating a wide scope.

---

**TUGBOAT CAPACITY ARRANGEMENT**

**What is the problem?** With tugboat capacity under pressure the tugboat capacity arrangement is increasingly in effect. This capacity arrangement is communicated via the HCC (Harbour Coordination Centre) by a tugboat company during times in which they cannot meet orders within two hours anymore. When in effect, the capacity arrangement requires all tugboat orders to be send three hours in advance, thereby given the tugboat company more time to react on the orders. Currently the tugboat that calls in the capacity arrangement is anonymised (still the tugboat companies are very reluctant to call the HCC to set an arrangement). As a result every tugboat company benefits from increased planning time, once a competitor calls in an arrangement. Do these anonymised capacity arrangements not cause unnecessary delays?
Research questions:
- What are the benefits of the capacity arrangement for the tugboat companies in the current form?
- What is the damage for shipping companies because they have to order sooner, despite that being unnecessary for three tug companies?

Relevance: It is unclear how many ‘unnecessary’ delays are caused by the capacity arrangements. It was beyond the scope of this document to investigate it in more depth.

Involved parties: Shipping companies, shipping agents, tugboat companies, pilots and Port Authority

Fits with Game structuring approach? Similar to the previous problem, this is not a wicked problem. The cause for delays in this case is clear (anonymising the capacity arrangements), yet the experience of it and solutions for it are different. Because GSMs can contrast conflicting interests and perspectives, an application can still have merit. Specifically it could show how the delays that are caused by the current capacity arrangement weigh up against the potential reputation damage the tugboat companies would suffer if the capacity arrangement was not anonymous. This could be used as input for recommendation for changing the capacity arrangement system.

Risks: It might be difficult to assess the cost for parties to order three hours in advance instead of two. The surplus in cost would reflect increased uncertainty in the planning of parties. Thus you would have to make this uncertainty clear. Besides that, the relevance of the problem is unknown.
This appendix describes the formulas underlying a mathematical (spreadsheet) model that can calculate the delay players experience and cause in all strategy profiles. Paragraph 4.6 already stated some general assumption on how delays are quantified in the model. To calculate the direction and height of a delay the relative position (smaller, equal or higher) between the received time, the communicated time, the derived perceived departure time, technical limitations (i.e. ship cannot depart before EoOT) and the actual departure time has to be taken into account. This is done slightly different for each player, because they experience delays differently. For example a delayed ship does not mean that the NSP are delayed. Table 12 shows the structure of the delay matrix. The matrix can be divided into several sections that have the same assumption and kind of formula to calculate delay. These formulates and assumptions will be explained hereafter.

### Table 16: Different sections of delay matrix

<table>
<thead>
<tr>
<th>Delay caused by</th>
<th>Delay caused for</th>
<th>Section 1</th>
<th>Section 2</th>
<th>Section 3</th>
<th>Section 4</th>
<th>Section 5</th>
<th>Section 6</th>
<th>Section 7</th>
<th>Section 8</th>
<th>Section 9</th>
<th>Section 10</th>
<th>Section 11</th>
<th>Section 12</th>
<th>Section 13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal</td>
<td>Terminal</td>
<td>Section A</td>
<td>Section B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shipping company</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Port authority</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pilots</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tugboats</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boatmen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SECTION A**

\[ \text{SECTION A} = \text{IF}(Q3\geq V17; Q3 - V15; \text{MAX}(-V16; Q3 - V15)) \]

Terminal causes delay for the terminal, shipping company and shipping agent if; the EoOT that the terminal communicates is higher than AEoOT (which is assumed 15:00 for every strategy profile). The size of this delay is the difference between the communicated EoOT and the theoretical fastest departure time (also 15:00).

These same player gain time if; the EoOT the terminal communicates is lower than the AEoOT. In that case the NSP can prepare the departure earlier, leading to time gains up to a maximum of 15 minutes.

**SECTION B**

\[ \text{SECTION B} = \text{MAX}(V15 - Q3; 0) \]

Delayed is caused if the EoOT that is communicated is lower than the AEoOT. If a EoOT is communicated that is higher than the AEoOT, no delay and no time gains are caused for the involved players in that section. The ship handling processes of these players are not sped up are slowed down in such cases.

**SECTION C**
Delay is caused if the ETD communicated by the player is larger than the ETD received and larger than the minimum ETD. The minimum ETD here is the ETD that needs to be communicated to achieve the theoretical fastest departure time, namely 14:45. The caused delay is the difference between the communicated ETD and the maximum of the received ETD and the minimum ETD.

Time gains are achieved if the received ETD is higher than the minimum ETD (means that there is potential for time gains) and the communicated ETD is lower than the minimum ETD. The time gain is equal to the minimum ETD minus the received ETD. Time gains are thus based on how far the ETD is moved to the minimum ETD, not how far below the minimum ETD it is. In this section only the shipping company can lower the ETD.

No delay is caused if both the received ETD and the communicated ETD are below the minimum ETD. In other cases the delay is calculated by the difference between the communicated ETD minus the maximum of the received ETD and the minimum ETD.

SECTION D

Delay is caused if the received ETD is lower than the AEoOT and the received ETD is lower than communicated ETD. The delay is than equal to the maximum of the difference between the received ETD minus the communicated ETD minus the delay already caused by the terminal and the difference between the received ETD and the AEoOT. In other cases the delay is equal to the maximum of zero and the difference between the AEoOT, the communicated ETD and the delay caused by terminal.

SECTION E

If these parties act on a departure order that has an ETD lower than the AEoOT, this results in delays. So if the received ETD is lower than the AEoOT time gains are achieved if the ETD that is communicated is higher than the received ETD. This time gain cannot be higher than the difference between the received ETD and the AEoOT. If the received ETD is higher than the AEoOT, the delay is set to 0.

SECTION F

Once a departure order is made definite, the NSP have to move to the berth. The NSP respond somewhat independently and simultaneously. The choice is made to assign any delay to the NSP that arrives the latest (if the response time is later than the requested arrival time). If multiple NSP arrive equally late to a departure order the delay they cause is split over evenly over these NSP.

SECTION G
The only difference between this section and the previous is that delays are caused by the NSP if the respond later than the AEoOT (15:00), rather than the minimum ETD (14:45).

SECTION I

The last row of the delay matrix sums all earlier delays. This leads to the experienced delay per player.
This appendix explains how the cost parameters used in the simulation model were acquired. The following formula is used to calculate the delay cost experienced by a player:

$$\sum (\text{Delay experienced} \times \text{delay cost per hour} + \text{delay caused for a player} \times \text{chargeable cost for that delay} - \text{delay experienced because of a player} \times \text{chargeable cost for that delay})$$

This formula needs to be specified to every player. This means that for every party two cost parameters need to be estimated; the delay cost per hour and the chargeable delay cost from one player to another per hour. The delay cost per hour for a player are assumed to be equal to the opportunity cost of that player (the revenue a player could have earned per hour, if not delayed). Some of the chargeable costs can be found on public documents, others were acquired through inquiries of experts at the Port Authority. Table 12 and 13 give an overview of the cost parameter that are used. The following paragraph will show the calculation behind each of these parameters.

<table>
<thead>
<tr>
<th>Players</th>
<th>1500 TEU</th>
<th>16000 TEU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal</td>
<td>14535</td>
<td>31000</td>
</tr>
<tr>
<td>Shipping Company</td>
<td>3500</td>
<td>10000</td>
</tr>
<tr>
<td>Shipping Agent</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Port Authority</td>
<td>290</td>
<td>1705</td>
</tr>
<tr>
<td>Pilot</td>
<td>891</td>
<td>2000</td>
</tr>
<tr>
<td>Tugboat Company</td>
<td>500</td>
<td>2933</td>
</tr>
<tr>
<td>Boatmen</td>
<td>220</td>
<td>1800</td>
</tr>
</tbody>
</table>
Table 18: Delay cost matrix (experienced cost in euro per hour)

<table>
<thead>
<tr>
<th>Player causing delay</th>
<th>Player experiencing delay</th>
<th>Terminal</th>
<th>Shipping company</th>
<th>Shipping Agent</th>
<th>Port Authority</th>
<th>Pilot</th>
<th>Tugboat Company</th>
<th>Boatmen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal</td>
<td>0</td>
<td>1500 TEU: 3500 16000 TEU: 10000</td>
<td>0</td>
<td>0</td>
<td>101</td>
<td>1500 TEU 465 16000 TEU: 930</td>
<td>1500 TEU: 147 16000 TEU: 266</td>
<td></td>
</tr>
<tr>
<td>Shipping company</td>
<td>14535/16000 TEU: 31000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>101</td>
<td>1500 TEU 465 16000 TEU: 930</td>
<td>1500 TEU: 147 16000 TEU: 266</td>
<td></td>
</tr>
<tr>
<td>Shipping agent</td>
<td>0</td>
<td>1500 TEU: 3500 16000 TEU: 10000</td>
<td>0</td>
<td>0</td>
<td>101</td>
<td>1500 TEU 465 16000 TEU: 930</td>
<td>1500 TEU: 147 16000 TEU: 266</td>
<td></td>
</tr>
<tr>
<td>Port Authority</td>
<td>0</td>
<td>1500 TEU: 3500 16000 TEU: 10000</td>
<td>0</td>
<td>0</td>
<td>101</td>
<td>1500 TEU 465 16000 TEU: 930</td>
<td>1500 TEU: 147 16000 TEU: 266</td>
<td></td>
</tr>
<tr>
<td>Pilot</td>
<td>0</td>
<td>1500 TEU: 891 16000 TEU: 2000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Tugboat company</td>
<td>0</td>
<td>1500 TEU: 500 16000 TEU: 2931</td>
<td>0</td>
<td>0</td>
<td>101</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
**TERMINAL COST**

The revenue of a terminal is determined by the number of containers it handles per hour. The opportunity cost of an hour delay in the departure of a ship is then determined by the number of containers the terminal could have handled for a similar ship per hour (assuming that there is enough demand for the services of a terminal). However, ships don’t always use their full capacity, nor do they offload all their cargo at Rotterdam. The load factor and the discharge rate have to be taken into account.

The average load factor for the Far East – Europe shipping rout was 84% in 2012 [Alphaliner, 2013]. Another source states: “According to an analysis of the first quarter by Drewry, the utilisation level of ships on the major east-west and north-south headhaul routes fell to 83%, compared with 85% for the same period of 2014 and the 87% recorded in Q4 2014” [The Loadstar, 2015]. The load factor in the cost calculations is therefore assumed to be 85%.

The rate of discharge has been calculated with the use of berth registration (over 2014) from the Port Authority. The average rate of discharge for all container sizes is 0.35. When different ship sizes are taken into account it can be seen that the average rate of discharge is 0.40 for ships with a TEU smaller then 4000 and 0.20 for ships larger than 10000 TEU. The data furthermore shows that there is no significant difference in the offload and load rate for a particular vessel size and that virtually all ships in the Port of Rotterdam load and offload during a trip to the port (97%).

The previous assumptions allow for an estimation of the number of containers handled for a certain ship size. The fee that terminals charge for a handling a container are called terminal handling charges (THC) and the average THC in Rotterdam are €171 for combined containers [European Commission Competition, 2009]. The total revenue for terminal for a ship are thus €171 times the number of containers handled. To get to the hourly opportunity, the final missing piece is the average time in which the terminal earns it revenue. Data on ship visits (over 2014) has been analysed to calculate this time. The average time a containership lays at a terminal berth in Rotterdam is equal to 13 hours. For ships with a Dead Weight Ton between 10000 and 20000 (A rule of thumb is; 1 TEU = 10 DWT), which is a proxy for a 1500 TEU ship the average berth time is 11 hours. Ships with a DWT larger than 150000 meanwhile have an average of 30 hours of berth time. Finally, the hourly opportunity cost of a terminal are;

\[
\text{Resulting in hourly delay cost for a terminal of €16000 in case a 1500 TEU ship is delayed and €31000 in case it regards a 16000 TEU ship.}
\]

Regarding the delays costs a terminal charges; Experts at the Port Authority state that it is not common for a terminal to claim compensation for delays they experience to parties other than a shipping company. The Service Level Agreements between terminals and shipping companies in all likelihood contain penalties for delaying one another. The height of these penalties are not public knowledge, nor knowledge available within the Port Authority. An inquiry at a terminal to gain this information unfortunately failed. That is why these cost are assumed to be equal to the hourly delay cost of a terminal and shipping company respectively. In other words, these parties fully compensate each other for delays caused.

**SHIPPING COMPANY DELAY COST:**
A representative from Maersk shipping line has estimated the average delay cost for their ships as €3500 per hour. At the same time he emphasised that the situation is very important, the delay cost can range to €10000 per hour, depending on the type of ship and schedule. For the model in this report the hourly delay cost for 1500 and 16000 TEU ships are assumed €3500 and €10000 respectively.

The delay cost a shipping company charges to a terminal, shipping agent or port authority are set equal to the hourly delay cost of a shipping company. According to experts at the Port Authority, the delay cost charged to NSP are often subject to negotiations. Commonly the NSP causing the delay offers the next departure for free. Hence the chargeable delay cost from the shipping company are assumed equal to the hourly delay cost of the NSP.

**SHIPPING AGENT DELAY COST**

Shipping agent are paid per port call or per vessel they service. A powerpoint presentation from the Port Authority on the contractual relationships between nautical supply chain parties estimates the agency fees to be €2000 per ship. With the average port stay time being 13 hours, the delay cost per hour are assumed to be €150 (€2000 / 13 hours).

According to experts at the port authority, agents do not charge delay costs to other parties (Bob Iken and Ben van Scherpenzeel, personal communication, n.d.). The chargeable delay cost are therefor assumed €0.

**PORT AUTHORITY DELAY COST**

The 2014 annual account of the Port Authority shows the revenue gained by port dues is €292 million [Port of Rotterdam, 2015e]. A delayed departure for the Port Authority means that a berth is occupied by a ship that does not bring in extra revenue, since port dues are not variable to time. The opportunity cost are thus equal to the port dues that could have been earned by the port authority, should the ship not have been delayed.

The Port Authority published a document which works out a few example calculations for port dues [Port of Rotterdam, 2015c]. The port dues rates differ for short sea and deep sea shipping. Container ships under 3000 TEU are generally called feeders. These type of ships are used for short sea shipping. The 1500 TEU ship in the model is thus assumed to be used for short sea transhipments, while the 16000 TEU ship is used for deep sea shipping. The port dues of a 1500 ship consists of dues related to the cargo and dues related to the GT-size of the ship. A 1500 ship approximately has a Gross Tonnage of 15000. The port dues related to the GT-size of the ship are then the GT-tariff of €0.175 * 15000 GT = €2625. The dues related to the cargo are calculated by multiplying the cargo tonnage, a switch percentage of 50.3% and a cargo tariff of €0.446. The tonnage of the cargo is estimated as 15000 GT * load factor of 0.85 * a rate of discharge of 0.4 = 5100. Finally, the port dues related to cargo are 5100 * 0.503*€0.446 =€1144. The total port dues for a 1500 TEU ship are 3769. This amount, divided by the average time a ship with that capacity occupies a berth (13 hours), forms the hourly delay cost of the Port Authority €290.

The pilot tariff for a departure is primarily dependent on two factor; the actual draft of the ship that needs a pilot and the route that the ship needs to travel [Loodswezen, 2015]. Berth registration data from the Port Authority (over 2014) shows that the average of the maximum draft of a 1500 TEU and 16000 TEU container ship is 8.2m and 15.8m
respectively. Of course the actual draft will be dependent on the amount of cargo a ship is carrying and not necessarily equal to the maximum draft. Another source shows the average draft of containerships per TEU to be roughly similar to the earlier mentioned figures [Rodrigue, 2015]. Since the tariff is too a larger extent determined by the route, the actual draft for the 1500 TEU ship will be assumed 8m and for the 16000 TEU ship 15m.

To calculate opportunity costs for NSP, it is necessary to estimate the average time they need to service a vessel. That depends on the distance they have to travel; the terminal the vessel is departing from. The berth registration from the Port Authority (from the year 2014) shows that for 1500 TEU ships; 34% departs from the Amazonehaven, 37% departs from the Yangtzekanaal, 10% departs from the Alexiahaven and 19% departs from other parts in the port (quite evenly spread). Furthermore ships this size cannot reach Moerdijk (which would imply a significant increase in travel distance). For 16000 TEU ships the data shows that; 37% departs from the Amazonehaven, 43% departs from the Europahaven, 19% departs from the Yangtzekanaal. ALL these harbours are in the Maasvlakte Area. The above has been visualised in figure 18 (image adopted from [Port of Rotterdam, 2015a]).

For a departure, pilots get on board of a ship at the terminal berth, and get off board the Maas Center Buoy. There, a special pilot ship picks the pilot up (see figure 19 and 20). This rendezvous point is a few kilometres out of the coast line. The time a ship passes the low light landmark is registered by the Port Authority. Rounded off, this trip takes about 1 hour both ship sizes taken into account. The time needed to get from the Low Light to the Maas Center Buoy was estimated (approx. 30 minutes) by looking at several vessel tracks at www.marinetraffic.com [Marine Traffic, 2015b]. Adding the timeframe of a departure order (2 hours), which is needed for planning and pilots travelling to the terminal, to the average travel time, lead to a total service time of 3.5 hours. The experienced delay costs per hour for pilots servicing a 1500 TEU ship are then €891 (3117 / 3.5) and €2000 (7001 / 3.5) for a 16000 TEU ship.

Meanwhile the delay costs charged by pilots are stated as 101 per hour, no matter the shipsize [Loodswezen, 2015]. Experts from the Port Authority stated that normally NSP do not charge each other delay costs. This is incorporated as such in the model.

![Figure 35: Departures of containerships from Port of Rotterdam](image)
TUGBOAT COMPANY DELAY COST

The tug tariffs for a departure are dependent on the route and the length of the ship. The route for the investigated ship sizes is from the Maasvlakte area to sea [Port of Rotterdam, 2015d]. The length of a 1500 TEU ship is assumed to be around 165 meter [Knud E. Hansen A/S, 2015]. The length of a 16000 TEU ship is assumed to be around 400 meter [Marine Traffic, 2015a]. A duty officer from the Harbour Coordination Centre provided information on the where tugboats normally uncouple (Willem Maan, personal communication, 16-07-2015). This is roughly at the mouth of the Beerkanaal, in line with the Low Light landmark (see figure 18). This takes the tugboats about one hour of travel time, according to the berth registration data from the Port Authority. Adding the departure order time frame of two hours, leads to an average total service time of three hours. Assuming the 16000 TEU ships needs two tugboats, the related experienced hourly delay cost are; €500 (1500 / 3) for 1500 TEU ships and €2933 (€8800 /3) for 16000 TEU ships. Meanwhile, the delay cost the tugboat companies charge to parties (except for other NSP, as explained earlier) are €465 for 1500 TEU ships and €930 for 16000 ships [Port of Rotterdam, 2015d].
The tariffs the boatmen charge are dependent on the length of a ship [Port of Rotterdam, 2015d]. It was assumed earlier that a 1500 TEU ship is 165 meters, while a 16000 TEU ship is 400 meters long. The berth registration data from the Port Authority shows that boatmen have an average service time at the berth of about 15 minutes. The total service time of boatmen is there for assumed equal to the timeframe of the departure order (2 hours). This leads to hourly experienced cost of €221 for a 1500 TEU ship and €1800 for a 16000 TEU ship.

The waiting costs charged by the boatmen is also dependent on the length of the serviced ship. The charged cost for a 1500 TEU ship are €147, and €266 for a 16000 TEU ship. Boatmen do not charge these costs to other NSP.
This appendix describes the code for the simulation model, as well as the experimental design.

CODE

globals[  
  actual-end-of-ops-time  
  communicated-end-of-ops-time  
  desired-arrival-time-of-nsp ;;nsp = nautical service providers  
  response-time-pilot  
  response-time-boatmen  
  response-time-tugboat-company  
  departure-time  
  theoretical-fastest-departure-time  
  minimum-ETD  
  max-time-parties-can-win  
  ETD-by-terminal  
  ETD-by-shipping-company  
  desired-ETD  
  feasible-ETD-port-authority  
  feasible-ETD-pilot  
  feasible-ETD-tugboat-company  
  feasible-ETD-boatmen  

delay-terminal-to-terminal  
  delay-terminal-to-shipping-company  
  delay-terminal-to-shipping-agent  
  delay-terminal-to-port-authority  
  delay-terminal-to-pilot  
  delay-terminal-to-tugboat-company  
  delay-terminal-to-boatmen  

delay-shipping-company-to-terminal  
  delay-shipping-company-to-shipping-company  
  delay-shipping-company-to-shipping-agent  
  delay-shipping-company-to-port-authority  
  delay-shipping-company-to-pilot  
  delay-shipping-company-to-tugboat-company  
  delay-shipping-company-to-boatmen  

delay-shipping-agent-to-terminal  
  delay-shipping-agent-to-shipping-company  
  delay-shipping-agent-to-shipping-agent  
  delay-shipping-agent-to-port-authority  
  delay-shipping-agent-to-pilot  
  delay-shipping-agent-to-tugboat-company  
  delay-shipping-agent-to-boatmen  

delay-port-authority-to-terminal  

delay-port-authority-to-shipping-company
delay-port-authority-to-shipping-agent
delay-port-authority-to-port-authority
delay-port-authority-to-pilot
delay-port-authority-to-tugboat-company
delay-port-authority-to-boatmen
delay-pilot-to-terminal
delay-pilot-to-shipping-company
delay-pilot-to-shipping-agent
delay-pilot-to-port-authority
delay-pilot-to-pilot
delay-pilot-to-tugboat-company
delay-pilot-to-boatmen
delay-pilot-response-to-terminal
delay-pilot-response-to-shipping-company
delay-pilot-response-to-shipping-agent
delay-pilot-response-to-port-authority
delay-pilot-response-to-pilot
delay-pilot-response-to-tugboat-company
delay-pilot-response-to-boatmen
delay-tugboat-company-to-terminal
delay-tugboat-company-to-shipping-company
delay-tugboat-company-to-shipping-agent
delay-tugboat-company-to-port-authority
delay-tugboat-company-to-pilot
delay-tugboat-company-to-tugboat-company
delay-tugboat-company-to-boatmen
delay-tugboat-company-response-to-terminal
delay-tugboat-company-response-to-shipping-company
delay-tugboat-company-response-to-shipping-agent
delay-tugboat-company-response-to-port-authority
delay-tugboat-company-response-to-pilot
delay-tugboat-company-response-to-tugboat-company
delay-tugboat-company-response-to-boatmen
delay-boatmen-to-terminal
delay-boatmen-to-shipping-company
delay-boatmen-to-shipping-agent
delay-boatmen-to-port-authority
delay-boatmen-to-pilot
delay-boatmen-to-tugboat-company
delay-boatmen-to-boatmen
delay-boatmen-response-to-terminal
delay-boatmen-response-to-shipping-company
delay-boatmen-response-to-shipping-agent
delay-boatmen-response-to-port-authority
delay-boatmen-response-to-pilot
delay-boatmen-response-to-tugboat-company
delay-boatmen-response-to-boatmen
total-delay-terminal
total-delay-shipping-company
total-delay-shipping-agent
total-delay-port-authority
total-delay-pilot
total-delay-tugboat-company
total-delay-boatmen
total-delay-system

;;;;;;;cost globals;;;;;

cost-of-hour-delay-terminal
cost-of-hour-delay-shipping-company
cost-of-hour-delay-shipping-agent
cost-of-hour-delay-port-authority
cost-of-hour-delay-pilot
cost-of-hour-delay-tugboat-company
cost-of-hour-delay-boatmen

costable-waiting-costs-terminal-to-shipping-company
costable-waiting-costs-terminal-to-shipping-agent
costable-waiting-costs-terminal-to-port-authority
costable-waiting-costs-terminal-to-pilot
costable-waiting-costs-terminal-to-tugboat-company
costable-waiting-costs-terminal-to-boatmen

costable-waiting-costs-shipping-company-to-terminal
costable-waiting-costs-shipping-company-to-shipping-agent
costable-waiting-costs-shipping-company-to-port-authority
costable-waiting-costs-shipping-company-to-pilot
costable-waiting-costs-shipping-company-to-tugboat-company
costable-waiting-costs-shipping-company-to-boatmen

costable-waiting-costs-shipping-agent-to-terminal
costable-waiting-costs-shipping-agent-to-shipping-company
costable-waiting-costs-shipping-agent-to-port-authority
costable-waiting-costs-shipping-agent-to-pilot
costable-waiting-costs-shipping-agent-to-tugboat-company
costable-waiting-costs-shipping-agent-to-boatmen

costable-waiting-costs-port-authority-to-terminal
costable-waiting-costs-port-authority-to-shipping-company
costable-waiting-costs-port-authority-to-shipping-agent
costable-waiting-costs-port-authority-to-pilot
costable-waiting-costs-port-authority-to-tugboat-company
costable-waiting-costs-port-authority-to-boatmen

costable-waiting-costs-pilot-to-terminal
costable-waiting-costs-pilot-to-shipping-company
costable-waiting-costs-pilot-to-shipping-agent
costable-waiting-costs-pilot-to-port-authority
chargeable-waiting-costs-pilot-to-tugboat-company
chargeable-waiting-costs-pilot-to-boatmen

chargeable-waiting-costs-tugboat-company-to-terminal
chargeable-waiting-costs-tugboat-company-to-shipping-company
chargeable-waiting-costs-tugboat-company-to-shipping-agent
chargeable-waiting-costs-tugboat-company-to-port-authority
chargeable-waiting-costs-tugboat-company-to-pilot
chargeable-waiting-costs-tugboat-company-to-boatmen

chargeable-waiting-costs-boatmen-to-terminal
chargeable-waiting-costs-boatmen-to-shipping-company
chargeable-waiting-costs-boatmen-to-shipping-agent
chargeable-waiting-costs-boatmen-to-port-authority
chargeable-waiting-costs-boatmen-to-pilot
chargeable-waiting-costs-boatmen-to-tugboat-company

paid-delay-costs-terminal
paid-delay-costs-shipping-company
paid-delay-costs-shipping-agent
paid-delay-costs-port-authority
paid-delay-costs-pilot
paid-delay-costs-tugboat-company
paid-delay-costs-boatmen

received-delay-costs-terminal
received-delay-costs-shipping-company
received-delay-costs-shipping-agent
received-delay-costs-port-authority
received-delay-costs-pilot
received-delay-costs-tugboat-company
received-delay-costs-boatmen

experienced-costs-terminal
experienced-costs-shipping-company
experienced-costs-shipping-agent
experienced-costs-port-authority
experienced-costs-pilot
experienced-costs-tugboat-company
experienced-costs-boatmen
experienced-costs-system

]
;;turtles-own[

;;patches-own[

to setup
  clear-all
  setup-world
  set-globals
  create-players
  reset-ticks
end

to go
  terminal-communicates-order
  shipping-company-communicates-order
  shipping-agent-communicates-order
  port-authority-assesses-order
  pilot-assesses-order
  tugboat-company-assesses-order
  boatmen-acts-assesses-order
  nsp-respond
  departure
  delay-calculations
  stop
end

to setup-world
  ask patches with [pycor >= 3]
  [set pcolor grey]
  ask patches with [pycor < 3]
  [set pcolor blue]
end

to set-globals
  set actual-end-of-ops-time 15
  set max-time-parties-can-win 0.25
  set theoretical-fastest-departure-time actual-end-of-ops-time
  set minimum-ETD 14.75
end

to create-players

  create-terminals 1 [set size 12]
  set-default-shape terminals "container"
  ask terminals [setxy 0 6]
  ask terminals [set color green]

  create-shipping-companies 1 [set size 6]
  set-default-shape shipping-companies "boat"
  ask shipping-companies [setxy 0 -3]
  ask shipping-companies [set color red]
create-shipping-agents 1 [set size 2]
set-default-shape shipping-agents "house"
ask shipping-agents [setxy -13 6]
ask shipping-agents [set color blue]

create-port-authorities 1 [set size 4]
set-default-shape port-authorities "police"
ask port-authorities [setxy -13 -13]
ask port-authorities [set color yellow]

create-pilots 1 [set size 2]
set-default-shape pilots "person"
ask pilots [setxy -5 -13]
ask pilots [set color orange]

create-tugboat-companies 1 [set size 2]
set-default-shape tugboat-companies "boat top"
ask tugboat-companies [setxy 5 -13]
ask tugboat-companies [set color brown]

create-boatmen 1 [set size 2]
set-default-shape boatmen "truck"
ask boatmen [setxy 13 -13]
ask boatmen [set color turquoise]

create-messages 1 [set size 2]
set-default-shape messages "telephone"
ask messages [setxy 0 -7]
ask messages [set color pink]
end

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;GO;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

to terminal-communicates-order
ask messages [move-to-terminal 0]; animation
set communicated-end-of-ops-time (actual-end-of-ops-time + decision-terminal)
set ETD-by-terminal communicated-end-of-ops-time + 0.25
end

to shipping-company-communicates-order
ask messages [move-to-shipping-company 1]; animation
set desired-arrival-time-of-nsp (communicated-end-of-ops-time - 0.25 + decision-shipping-company)
set ETD-by-shipping-company (desired-arrival-time-of-nsp + 0.5)
end

to shipping-agent-communicates-order
ask messages [move-to-shipping-agent 2]; animation
set desired-ETD (desired-arrival-time-of-nsp + 0.5 + decision-shipping-agent)
end
to port-authority- asses ses-order
ask messages [move-to port-authority 3] ;; animation
set feasible-ETD-port-authority (desired-ETD + decision-port-authority)
end

to pilot- assesses-order
ask messages [move-to pilot 4] ;; animation
set feasible-ETD-pilot Max (list (desired-ETD + decision-pilot) (feasible-ETD-port-authority))
end

to tugboat-company- assesses-order
ask messages [move-to tugboat-company 5] ;; animation
set feasible-ETD-tugboat-company Max (list (desired-ETD + decision-tugboat-company) (feasible-ETD-pilot))
end

to boatmen- acts- assesses-order
ask messages [move-to a-boatmen 6] ;; animation
set feasible-ETD-boatmen Max (list (desired-ETD + decision-boatmen) (feasible-ETD-tugboat-company)) ;; note that this feasible time makes the departure order final.
end

to ns p- respond
ask pilots [move-to shipping-company 1] ;; animation
set response-time-pilot (feasible-ETD-boatmen - 0.5 + response-pilot)
ask tugboat-companies [move-to shipping-company 1] ;; animation
set response-time-tugboat-company (feasible-ETD-boatmen - 0.5 + response-tugboat-company)
ask boatmen [move-to shipping-company 1] ;; animation
set response-time-boatmen (feasible-ETD-boatmen - 0.5 + response-boatmen)
end

to departure
set departure-time max (list (response-time-boatmen + 0.5) (response-time-tugboat-company + 0.5) (response-time-pilot + 0.5) actual-end-of-ops-time)
ask shipping-companies [setxy 13 -3] ;; animation
ask pilots [setxy 10 -3] ;; animation
ask tugboat-companies [setxy 10 -3] ;; animation
ask boatmen [setxy 10 -3] ;; animation
;; print desired-ETD
;; print departure-time
end

;; delay calculations 7 X 10 matrix or 10 X 7 matrix
;; cost calculations 7 x 7 matrix possible 8x8 with last row and column being sums of rows and columns.
;; delay caused by terminal
to delay-calculations

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

;;delay from terminal to terminal
ifelse (ETD-by-terminal >= minimum-ETD) [set delay-terminal-to-terminal (ETD-by-terminal - theoretical-fastest-departure-time)]
[set delay-terminal-to-terminal max (list (- max-time-parties-can-win) (ETD-by-terminal - theoretical-fastest-departure-time))]

;;delay from terminal to shipping-company
ifelse (ETD-by-terminal >= minimum-ETD) [set delay-terminal-to-shipping-company (ETD-by-terminal - theoretical-fastest-departure-time)]
[set delay-terminal-to-shipping-company max (list (- max-time-parties-can-win) (ETD-by-terminal - theoretical-fastest-departure-time))]

;; delay from terminal to shipping-agent
ifelse (ETD-by-terminal >= minimum-ETD) [set delay-terminal-to-shipping-agent (ETD-by-terminal - theoretical-fastest-departure-time)]
[set delay-terminal-to-shipping-agent max (list (- max-time-parties-can-win) (ETD-by-terminal - theoretical-fastest-departure-time))]

;;delay from terminal to port authority
set delay-terminal-to-port-authority max (list(theoretical-fastest-departure-time - (ETD-by-terminal)) 0)

;;delay from terminal to pilot
set delay-terminal-to-pilot max (list(theoretical-fastest-departure-time - (ETD-by-terminal)) 0)

;;delay from terminal to tugboat-company
set delay-terminal-to-tugboat-company max (list(theoretical-fastest-departure-time - (ETD-by-terminal)) 0)

;;delay from terminal to boatmen
set delay-terminal-to-boatmen max (list(theoretical-fastest-departure-time - (ETD-by-terminal)) 0)

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

;; delay from shipping company to terminal
ifelse (ETD-by-shipping-company > ETD-by-terminal and ETD-by-shipping-company >= minimum-ETD)
[set delay-shipping-company-to-terminal ETD-by-shipping-company - Max (list(ETD-by-terminal) (minimum-ETD))]
[ifelse ETD-by-shipping-company <= minimum-ETD and ETD-by-terminal <= minimum-ETD [set delay-shipping-company-to-terminal 0]
[set delay-shipping-company-to-terminal ETD-by-shipping-company - max (list (ETD-by-terminal) (minimum-ETD))]]]]
;; set delay-shipping-company-to-shipping-company
set delay-shipping-company-to-shipping-company delay-shipping-company-to-terminal

;; set delay-shipping-company-to-shipping-agent
set delay-shipping-company-to-shipping-agent delay-shipping-company-to-terminal

;; delay-shipping-company-to-port-authority
ifelse (ETD-by-terminal < theoretical-fastest-departure-time and ETD-by-shipping-company > ETD-by-terminal) [  
  set delay-shipping-company-to-port-authority max (list (ETD-by-terminal - ETD-by-shipping-company - delay-terminal-to-port-authority) (ETD-by-terminal - theoretical-fastest-departure-time))]

[set delay-shipping-company-to-port-authority max (list (theoretical-fastest-departure-time - ETD-by-shipping-company - delay-terminal-to-port-authority) (0))]

;; set delay-shipping-company-to-pilot
ifelse (ETD-by-terminal < theoretical-fastest-departure-time and ETD-by-shipping-company > ETD-by-terminal) [  
  set delay-shipping-company-to-pilot max (list (ETD-by-terminal - ETD-by-shipping-company - delay-terminal-to-pilot) (ETD-by-terminal - theoretical-fastest-departure-time))]

[set delay-shipping-company-to-pilot max (list (theoretical-fastest-departure-time - ETD-by-shipping-company - delay-terminal-to-pilot) (0))]

;; delay-shipping-company-to-tugboat-company
ifelse (ETD-by-terminal < theoretical-fastest-departure-time and ETD-by-shipping-company > ETD-by-terminal) [  

[set delay-shipping-company-to-tugboat-company max (list (theoretical-fastest-departure-time - ETD-by-shipping-company - delay-terminal-to-tugboat-company) (0))]

;; delay-shipping-company-to-boatmen
ifelse (ETD-by-terminal < theoretical-fastest-departure-time and ETD-by-shipping-company > ETD-by-terminal) [  
  set delay-shipping-company-to-boatmen max (list (ETD-by-terminal - ETD-by-shipping-company - delay-terminal-to-boatmen) (ETD-by-terminal - theoretical-fastest-departure-time))]

[set delay-shipping-company-to-boatmen max (list (theoretical-fastest-departure-time - ETD-by-shipping-company - delay-terminal-to-boatmen) (0))]

;.................................................................;Shipping agent;.................................................................;

;; delay-shipping-agent-to-terminal
ifelse (desired-ETD > ETD-by-shipping-company and desired-ETD >= minimum-ETD) [  
  set delay-shipping-agent-to-terminal ETD-by-shipping-company - Max (list(ETD-by-shipping-company) (minimum-ETD))]

[ifelse desired-ETD <= minimum-ETD and ETD-by-shipping-company <= minimum-ETD [set delay-shipping-agent-to-terminal 0]  


[set delay-shipping-agent-to-terminal desired-ETD - max (list (ETD-by-shipping-company) (minimum-ETD)) ] ]

;; delay-shipping-agent-to-shipping-company
set delay-shipping-agent-to-shipping-company delay-shipping-agent-to-terminal

;; delay-shipping-agent-to-shipping-agent
set delay-shipping-agent-to-shipping-agent delay-shipping-agent-to-terminal

;; delay-shipping-agent-to-port-authority
ifelse (ETD-by-shipping-company < theoretical-fastest-departure-time and desired-ETD < ETD-by-shipping-company) [set delay-shipping-agent-to-port-authority (ETD-by-shipping-company - desired-ETD)]

;; delay-shipping-agent-to-pilot
ifelse (ETD-by-shipping-company < theoretical-fastest-departure-time and desired-ETD < ETD-by-shipping-company) [set delay-shipping-agent-to-pilot (ETD-by-shipping-company - desired-ETD)]

;; delay-shipping-agent-to-tugboat-company
ifelse (ETD-by-shipping-company < theoretical-fastest-departure-time and desired-ETD < ETD-by-shipping-company) [set delay-shipping-agent-to-tugboat-company (ETD-by-shipping-company - desired-ETD)]

;; delay-shipping-agent-to-boatmen
ifelse (ETD-by-shipping-company < theoretical-fastest-departure-time and desired-ETD < ETD-by-shipping-company) [set delay-shipping-agent-to-boatmen (ETD-by-shipping-company - desired-ETD)]
set delay-shipping-agent-to-boatmen max (list (theoretical-fastest-departure-time - desired-ETD - delay-terminal-to-boatmen - delay-shipping-company-to-boatmen) (0)) ]]

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;Port Authority;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

;; delay-port-authority-to-terminal
ifelse (feasible-ETD-port-authority > desired-ETD and feasible-ETD-port-authority >= minimum-ETD) [set delay-port-authority-to-terminal feasible-ETD-port-authority - Max (list(desired-ETD) (minimum-ETD))]
ifelse feasible-ETD-port-authority <= minimum-ETD and desired-ETD <= minimum-ETD [set delay-port-authority-to-terminal 0]
ifelse desired-ETD >= minimum-ETD and feasible-ETD-port-authority < minimum-ETD [set delay-port-authority-to-terminal minimum-ETD - desired-ETD ]
ifelse delay-port-authority-to-terminal feasible-ETD-port-authority - max (list(desired-ETD) (minimum-ETD)) ] ]]

;; delay-port-authority-to-shipping-company
set delay-port-authority-to-shipping-company delay-port-authority-to-terminal

;; delay-port-authority-to-shipping-agent
set delay-port-authority-to-shipping-agent delay-port-authority-to-terminal

;; delay-port-authority-to-port-authority
ifelse (desired-ETD < theoretical-fastest-departure-time) [ set delay-port-authority-to-port-authority max (list(desired-ETD - feasible-ETD-port-authority) (desired-ETD - theoretical-fastest-departure-time)) ] [ set delay-port-authority-to-port-authority 0]

;; delay-port-authority-to-pilot
set delay-port-authority-to-pilot delay-port-authority-to-terminal

;; delay-port-authority-to-tugboat-company
set delay-port-authority-to-tugboat-company delay-port-authority-to-port-authority

;; delay-port-authority-to-boatmen
set delay-port-authority-to-boatmen delay-port-authority-to-port-authority

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;Pilot;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

;; delay-pilot-to-shipping-company
set delay-pilot-to-shipping-company delay-pilot-to-terminal

;; delay-pilot-to-shipping-agent
set delay-pilot-to-shipping-agent delay-pilot-to-terminal

;; delay-pilot-to-port-authority
ifelse (feasible-ETD-port-authority < theoretical-fastest-departure-time) [
  set delay-pilot-to-port-authority max (list (feasible-ETD-port-authority - feasible-ETD-pilot) (feasible-ETD-port-authority - theoretical-fastest-departure-time))]
  set delay-pilot-to-port-authority 0]

;; delay-pilot-to-pilot
set delay-pilot-to-pilot delay-pilot-to-port-authority

;; delay-pilot-to-tugboat-company
set delay-pilot-to-tugboat-company delay-pilot-to-port-authority

;; delay-pilot-to-boatmen
set delay-pilot-to-boatmen delay-pilot-to-port-authority

;..............................................................................;Tugboat company;..............................................................................;

;; delay-tugboat-company-to-terminal
ifelse (feasible-ETD-tugboat-company > feasible-ETD-pilot and feasible-ETD-tugboat-company >= minimum-ETD)
  [set delay-tugboat-company-to-terminal feasible-ETD-tugboat-company - Max (list (feasible-ETD-pilot) (minimum-ETD))]
  [ifelse feasible-ETD-tugboat-company <= minimum-ETD and feasible-ETD-pilot <= minimum-ETD [set delay-tugboat-company-to-terminal 0]

;; delay-tugboat-company-to-shipping-company
set delay-tugboat-company-to-shipping-company delay-tugboat-company-to-terminal

;; delay-tugboat-company-to-shipping-agent
set delay-tugboat-company-to-shipping-agent delay-tugboat-company-to-terminal

;; delay-tugboat-company-pilot-to-port-authority
ifelse (feasible-ETD-pilot < theoretical-fastest-departure-time) [
  set delay-tugboat-company-to-port-authority max (list (feasible-ETD-pilot - feasible-ETD-tugboat-company) (feasible-ETD-pilot - theoretical-fastest-departure-time))]
  set delay-tugboat-company-to-port-authority 0]

;; delay-tugboat-company-to-pilot
set delay-tugboat-company-to-pilot delay-tugboat-company-to-port-authority

;; delay-tugboat-company-to-tugboat-company
set delay-tugboat-company-to-tugboat-company delay-tugboat-company-to-port-authority

;; delay-tugboat-company-to-boatmen
set delay-tugboat-company-to-boatmen delay-tugboat-company-to-port-authority

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
set delay-tugboat-company-to-boatmen delay-tugboat-company-to-port-authority

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
set delay-boatmen-to-terminal
ifelse (feasible-ETD-boatmen > feasible-ETD-tugboat-company and feasible-ETD-boatmen >= minimum-ETD)
[set delay-boatmen-to-terminal feasible-ETD-boatmen - Max (list(feasible-ETD-tugboat-company) (minimum-ETD))]
[ifelse feasible-ETD-boatmen <= minimum-ETD and feasible-ETD-tugboat-company <= minimum-ETD [set delay-boatmen-to-terminal 0]
  [ifelse feasible-ETD-tugboat-company >= minimum-ETD and feasible-ETD-boatmen < minimum-ETD [set delay-boatmen-to-terminal minimum-ETD - feasible-ETD-tugboat-company]
    [set delay-boatmen-to-terminal feasible-ETD-boatmen - max (list (feasible-ETD-tugboat-company) (minimum-ETD))]]]

;; delay-boatmen-to-shipping-company
set delay-boatmen-to-shipping-company delay-boatmen-to-terminal

;; delay-tugboat-company-to-shipping-agent
set delay-boatmen-to-shipping-agent delay-boatmen-to-terminal

;; delay-boatmen-pilot-to-port-authority
ifelse (feasible-ETD-tugboat-company < theoretical-fastest-departure-time) [set delay-boatmen-to-port-authority max (list (feasible-ETD-tugboat-company - feasible-ETD-boatmen) (feasible-ETD-tugboat-company - theoretical-fastest-departure-time))]

set delay-boatmen-to-port-authority 0]

;; delay-boatmen-to-pilot
set delay-boatmen-to-pilot delay-boatmen-to-port-authority

;; delay-boatmen-to-tugboat-company
set delay-boatmen-to-tugboat-company delay-boatmen-to-port-authority

;; delay-boatmen-to-boatmen
set delay-boatmen-to-boatmen delay-boatmen-to-port-authority

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
);;;;;;;;;;;;;;;NSP responses;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

;; delay-pilot-response-to-terminal
;; response-time-pilot + 0.5 equals the ETD which is assumed by the pilot. I.e. it is assumed that nsp need half an hour to prepare a departure
ifelse (Max (list (response-time-pilot) (response-time-tugboat-company) (response-time-boatmen)) - response-time-pilot = 0) [ 
  ifelse (response-time-pilot + 0.5) >= minimum-ETD and feasible-ETD-boatmen <= minimum-ETD [ifelse response-time-pilot = response-time-tugboat-company [set delay-pilot-response-to-terminal ((response-time-pilot + 0.5) - minimum-ETD) / 2] [set delay-pilot-response-to-terminal ((response-time-pilot + 0.5) - minimum-ETD) / 1] ]
  [ifelse (response-time-pilot + 0.5) >= minimum-ETD and feasible-ETD-boatmen > minimum-ETD [ifelse response-time-pilot = response-time-tugboat-company [set delay-pilot-response-to-terminal ((response-time-pilot + 0.5) - feasible-ETD-boatmen) / 2] [set delay-pilot-response-to-terminal ((response-time-pilot + 0.5) - feasible-ETD-boatmen) / 1] ]
  [ifelse (response-time-pilot + 0.5) <= minimum-ETD and feasible-ETD-boatmen <= minimum-ETD [ifelse response-time-pilot = response-time-tugboat-company [set delay-pilot-response-to-terminal (feasible-ETD-boatmen - (response-time-pilot + 0.5)) / 2] [set delay-pilot-response-to-terminal (feasible-ETD-boatmen - (response-time-pilot + 0.5)) / 1] ]
  [set delay-pilot-response-to-terminal 0] ] [set delay-pilot-response-to-terminal 0] ;; non-negative delays

;; delay-pilot-response-to-shipping-company
set delay-pilot-response-to-shipping-company delay-pilot-response-to-terminal

;; delay-pilot-response-to-shipping-agent
set delay-pilot-response-to-shipping-agent delay-pilot-response-to-terminal

;; delay-pilot-response-to-port-authority
ifelse (Max (list (response-time-pilot) (response-time-tugboat-company) (response-time-boatmen)) - response-time-pilot = 0) [ 
  ifelse ((response-time-pilot + 0.5)) >= theoretical-fastest-departure-time and feasible-ETD-boatmen <= theoretical-fastest-departure-time [ifelse response-time-pilot = response-time-tugboat-company [set delay-pilot-response-to-port-authority (response-time-pilot + 0.5 - theoretical-fastest-departure-time) / 2] [set delay-pilot-response-to-port-authority (response-time-pilot + 0.5 - theoretical-fastest-departure-time) / 1] ]
  [set delay-pilot-response-to-port-authority 0] ] [set delay-pilot-response-to-port-authority 0] ;; non-negative delays

;; delay-pilot-response-to-pilot
set delay-pilot-response-to-pilot delay-pilot-response-to-port-authority
;; delay-pilot-response-to-tugboat-company
set delay-pilot-response-to-tugboat-company delay-pilot-response-to-port-authority

;; delay-pilot-response-to-boatmen
set delay-pilot-response-to-boatmen delay-pilot-response-to-port-authority

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

;; delay-tugboat-company-response-to-terminal

if delay-tugboat-company-response-to-terminal < 0 [set delay-tugboat-company-response-to-terminal 0]

;; delay-tugboat-company-response-to-shipping-company
set delay-tugboat-company-response-to-shipping-company delay-tugboat-company-response-to-terminal

;; delay-tugboat-company-response-to-shipping-agent

;; delay-tugboat-company-to-port-authority

if delay-tugboat-company-response-to-port-authority < 0 [set delay-tugboat-company-response-to-port-authority 0] ;; non-negative delays

;; delay-tugboat-company-response-to-pilot
set delay-tugboat-company-response-to-pilot delay-tugboat-company-response-to-port-authority

;; delay-tugboat-company-response-to-tugboat-company
set delay-tugboat-company-response-to-tugboat-company delay-tugboat-company-response-to-port-authority

;; delay-tugboat-company-response-to-boatmen
set delay-tugboat-company-response-to-boatmen delay-tugboat-company-response-to-port-authority

;;;;;;;;;;;;;;;;;;

;; delay-boatmen-response-to-terminal
ifelse (Max (list (response-time-pilot) (response-time-tugboat-company) (response-time-boatmen)) - response-time-boatmen = 0) [
  ifelse (response-time-boatmen + 0.5) >= minimum-ETD and feasible-ETD-boatmen <= minimum-ETD [ifelse response-time-pilot = response-time-tugboat-company [set delay-boatmen-response-to-terminal ((response-time-boatmen + 0.5) - minimum-ETD) / 2] [set delay-boatmen-response-to-terminal ((response-time-boatmen + 0.5) - minimum-ETD) / 1]]] [ifelse (response-time-boatmen + 0.5) >= minimum-ETD and feasible-ETD-boatmen >= minimum-ETD [ifelse response-time-pilot = response-time-tugboat-company [set delay-boatmen-response-to-terminal ((response-time-boatmen + 0.5) - feasible-ETD-boatmen) / 2] [set delay-boatmen-response-to-terminal ((response-time-boatmen + 0.5) - feasible-ETD-boatmen) / 1]]

[ifelse (response-time-boatmen + 0.5) <= minimum-ETD and feasible-ETD-boatmen <= minimum-ETD [ifelse response-time-pilot = response-time-tugboat-company [set delay-boatmen-response-to-terminal (feasible-ETD-boatmen - (response-time-boatmen + 0.5)) / 2] [set delay-boatmen-response-to-terminal (feasible-ETD-boatmen - (response-time-boatmen + 0.5)) / 1]]]
([set delay-boatmen-response-to-terminal 0 ] ) ] [set delay-boatmen-response-to-terminal 0]

;; delay-boatmen-response-to-shipping-company
set delay-boatmen-response-to-shipping-company delay-boatmen-response-to-terminal

;; delay-boatmen-response-to-shipping-agent
set delay-boatmen-response-to-shipping-agent delay-boatmen-response-to-terminal

if delay-boatmen-response-to-terminal < 0 [set delay-boatmen-response-to-terminal 0]

;; delay-boatmen-response-to-port-authority
ifelse (Max (list (response-time-pilot) (response-time-tugboat-company) (response-time-boatmen)) - response-time-boatmen = 0) [
  ifelse (response-time-boatmen + 0.5) >= theoretical-fastest-departure-time and feasible-ETD-boatmen <= theoretical-fastest-departure-time [ifelse response-time-pilot = response-time-tugboat-company [set delay-boatmen-response-to-port-authority ((response-time-boatmen + 0.5) - theoretical-fastest-departure-time) / 2] [set delay-boatmen-response-to-port-authority ((response-time-boatmen + 0.5) - theoretical-fastest-departure-time) / 1] ]
  [ifelse (response-time-boatmen + 0.5) >= theoretical-fastest-departure-time and feasible-ETD-boatmen >= theoretical-fastest-departure-time [ifelse response-time-pilot = response-time-tugboat-company [set delay-boatmen-response-to-port-authority ((response-time-boatmen + 0.5) - feasible-ETD-boatmen) / 2] [set delay-boatmen-response-to-port-authority ((response-time-boatmen + 0.5) - feasible-ETD-boatmen) / 1] ]
  [ifelse (response-time-boatmen + 0.5) <= theoretical-fastest-departure-time and feasible-ETD-boatmen <= theoretical-fastest-departure-time [ifelse response-time-pilot = response-time-tugboat-company [set delay-boatmen-response-to-port-authority (feasible-ETD-boatmen - (response-time-boatmen + 0.5)) / 2] [set delay-boatmen-response-to-port-authority (feasible-ETD-boatmen - (response-time-boatmen + 0.5)) / 1] ]
  [set delay-boatmen-response-to-port-authority 0 ] ] ] [set delay-boatmen-response-to-port-authority 0]

if delay-boatmen-response-to-port-authority < 0 [set delay-boatmen-response-to-port-authority 0] ;; non-negative delays

;; delay-boatmen-response-to-pilot
set delay-boatmen-response-to-pilot delay-boatmen-response-to-port-authority

;; delay-boatmen-response-to-tugboat-company
set delay-boatmen-response-to-tugboat-company delay-boatmen-response-to-port-authority

;; delay-boatmen-response-to-boatmen
set delay-boatmen-response-to-boatmen delay-boatmen-response-to-port-authority


set total-delay-system (total-delay-terminal + total-delay-shipping-company + total-delay-authority + total-delay-pilot + total-delay-tugboat-company + total-delay-boatmen)

ifelse ship-size = 1500 [set cost-of-hour-delay-terminal 14535] [set cost-of-hour-delay-terminal 31000]
ifelse ship-size = 1500 [set cost-of-hour-delay-shipping-company 3000] [set cost-of-hour-delay-shipping-company 10000]
set cost-of-hour-delay-shipping-agent 150 ;;
ifelse ship-size = 1500 [set cost-of-hour-delay-port-authority 290] [set cost-of-hour-delay-port-authority 1705]
ifelse ship-size = 1500 [set cost-of-hour-delay-pilot 891] [set cost-of-hour-delay-pilot 2000]
ifelse ship-size = 1500 [set cost-of-hour-delay-tugboat-company 500] [set cost-of-hour-delay-tugboat-company 2933]
ifelse ship-size = 1500 [set cost-of-hour-delay-boatmen 220] [set cost-of-hour-delay-boatmen 1800]

;;; chargeable waiting cost terminal to shipping company means; terminal can charge an x amount to a causer of delay.

ifelse delay-shipping-company-to-terminal > 0 [set chargeable-waiting-costs-terminal-to-shipping-company cost-of-hour-delay-terminal] [set chargeable-waiting-costs-terminal-to-shipping-company 0]
set chargeable-waiting-costs-terminal-to-shipping-agent 0
set chargeable-waiting-costs-terminal-to-port-authority 0
set chargeable-waiting-costs-terminal-to-pilot 0
set chargeable-waiting-costs-terminal-to-tugboat-company 0
set chargeable-waiting-costs-terminal-to-boatmen 0

ifelse delay-terminal-to-shipping-company > 0 [set chargeable-waiting-costs-shipping-company-to-terminal cost-of-hour-delay-shipping-company] [set chargeable-waiting-costs-shipping-company-to-terminal 0]
set chargeable-waiting-costs-shipping-company-to-port-authority cost-of-hour-delay-shipping-company
set chargeable-waiting-costs-shipping-company-to-pilot cost-of-hour-delay-pilot ;; If a ship is delayed by NSP, often it is agreed that the next departure service of that NSP is free of charge for the shipping company.
set chargeable-waiting-costs-shipping-company-to-tugboat-company cost-of-hour-delay-tugboat-company
set chargeable-waiting-costs-shipping-company-to-boatmen cost-of-hour-delay-boatmen

set chargeable-waiting-costs-shipping-agent-to-terminal 0
set chargeable-waiting-costs-shipping-agent-to-shipping-company 0
set chargeable-waiting-costs-shipping-agent-to-port-authority 0
set chargeable-waiting-costs-shipping-agent-to-pilot 0
set chargeable-waiting-costs-shipping-agent-to-tugboat-company 0
set chargeable-waiting-costs-shipping-agent-to-boatmen 0

set chargeable-waiting-costs-port-authority-to-terminal 0
set chargeable-waiting-costs-port-authority-to-shipping-company 0
set chargeable-waiting-costs-port-authority-to-shipping-agent 0
set chargeable-waiting-costs-port-authority-to-pilot 0
set chargeable-waiting-costs-port-authority-to-tugboat-company 0
set chargeable-waiting-costs-port-authority-to-boatmen 0

set chargeable-waiting-costs-pilot-to-terminal 101
set chargeable-waiting-costs-pilot-to-shipping-company 101
set chargeable-waiting-costs-pilot-to-shipping-agent 101
set chargeable-waiting-costs-pilot-to-port-authority 101
set chargeable-waiting-costs-pilot-to-tugboat-company 101
set chargeable-waiting-costs-pilot-to-boatmen 101

ifelse ship-size = 1500 [set chargeable-waiting-costs-tugboat-company-to-terminal 465] [set chargeable-waiting-costs-tugboat-company-to-terminal 930]
ifelse ship-size = 1500 [set chargeable-waiting-costs-tugboat-company-to-port-authority 465] [set chargeable-waiting-costs-tugboat-company-to-port-authority 930]
set chargeable-waiting-costs-tugboat-company-to-pilot 0
set chargeable-waiting-costs-tugboat-company-to-boatmen 0

ifelse ship-size = 1500 [set chargeable-waiting-costs-boatmen-to-terminal 147] [set chargeable-waiting-costs-boatmen-to-terminal 266]
ifelse ship-size = 1500 [set chargeable-waiting-costs-boatmen-to-shipping-company 147] [set chargeable-waiting-costs-boatmen-to-shipping-company 266]
ifelse ship-size = 1500 [set chargeable-waiting-costs-boatmen-to-shipping-agent 147] [set chargeable-waiting-costs-boatmen-to-shipping-agent 266]
ifelse ship-size = 1500 [set chargeable-waiting-costs-boatmen-to-port-authority 147] [set chargeable-waiting-costs-boatmen-to-port-authority 266]
set chargeable-waiting-costs-boatmen-to-pilot 0
set chargeable-waiting-costs-boatmen-to-tugboat-company 0

;; player charge waiting cost if they are delayed in some cases. Player do not compensate themself
;; players are not compensated if they are experience time gains.

set paid-delay-costs-terminal (chargeable-waiting-costs-shipping-company-to-terminal * delay-terminal-to-shipping-company +
chargeable-waiting-costs-shipping-agent-to-terminal * delay-terminal-to-shipping-agent +
chargeable-waiting-costs-port-authority-to-terminal * delay-terminal-to-port-authority +
chargeable-waiting-costs-pilot-to-terminal * delay-terminal-to-pilot +
chargeable-waiting-costs-tugboat-company-to-terminal * delay-terminal-to-tugboat-company +
chargeable-waiting-costs-boatmen-to-terminal * delay-terminal-to-boatmen)

set paid-delay-costs-shipping-company (chargeable-waiting-costs-terminal-to-shipping-company * delay-shipping-company-to-terminal +
chargeable-waiting-costs-shipping-agent-to-shipping-company * delay-shipping-company-to-shipping-agent +
chargeable-waiting-costs-port-authority-to-shipping-company * delay-shipping-company-to-port-authority +
chargeable-waiting-costs-pilot-to-shipping-company * delay-shipping-company-to-pilot +
chargeable-waiting-costs-tugboat-company-to-shipping-company * delay-
shipping-company-to-tugboat-company +
chargeable-waiting-costs-boatmen-to-shipping-company * delay-shipping-
company-to-boatmen)

set paid-delay-costs-shipping-agent (chargeable-waiting-costs-terminal-to-shipping-
agent * delay-shipping-agent-to-terminal +
chargeable-waiting-costs-shipping-company-to-shipping-agent * delay-shipping-
agent-to-shipping-company +
chargeable-waiting-costs-port-authority-to-shipping-agent * delay-shipping-agent-
to-port-authority +
chargeable-waiting-costs-pilot-to-shipping-agent * delay-shipping-agent-to-pilot +
chargeable-waiting-costs-tugboat-company-to-shipping-agent * delay-shipping-
agent-to-tugboat-company +
chargeable-waiting-costs-boatmen-to-shipping-agent * delay-shipping-agent-to-
boatmen)

set paid-delay-costs-port-authority (chargeable-waiting-costs-terminal-to-port-
authority * delay-port-authority-to-terminal +
chargeable-waiting-costs-shipping-company-to-port-authority * delay-port-authority-
to-shipping-company +
chargeable-waiting-costs-shipping-agent-to-port-authority * delay-port-authority-
to-shipping-agent +
chargeable-waiting-costs-pilot-to-port-authority * delay-port-authority-to-pilot +
chargeable-waiting-costs-tugboat-company-to-port-authority * delay-port-authority-
to-tugboat-company +
chargeable-waiting-costs-boatmen-to-port-authority * delay-port-authority-to-
boatmen)

;; also include delay of second decision of pilot (pilot-response)

set paid-delay-costs-pilot (chargeable-waiting-costs-terminal-to-pilot * (delay-pilot-
to-terminal + delay-pilot-response-to-terminal) +
chargeable-waiting-costs-shipping-company-to-pilot * (delay-pilot-to-shipping-
company + delay-pilot-response-to-shipping-company) +
chargeable-waiting-costs-shipping-agent-to-pilot * (delay-pilot-to-shipping-agent +
delay-pilot-response-to-shipping-agent) +
chargeable-waiting-costs-port-authority-to-pilot * (delay-pilot-to-port-authority +
delay-pilot-response-to-port-authority) +
chargeable-waiting-costs-tugboat-company-to-pilot * (delay-pilot-to-tugboat-
company + delay-pilot-response-to-tugboat-company) +
chargeable-waiting-costs-boatmen-to-pilot * (delay-pilot-to-boatmen + delay-
pilot-response-to-boatmen))

set paid-delay-costs-tugboat-company (chargeable-waiting-costs-terminal-to-
tugboat-company * (delay-tugboat-company-to-terminal + delay-tugboat-company-
response-to-terminal) +
chargeable-waiting-costs-shipping-company-to-tugboat-company * (delay-
tugboat-company-to-shipping-company + delay-tugboat-company-response-to-shipping-
company) +
chargeable-waiting-costs-shipping-agent-to-tugboat-company * (delay-tugboat-
company-to-shipping-agent + delay-tugboat-company-response-to-shipping-agent) +
chargeable-waiting-costs-boatmen-to-tugboat-company * (delay-tugboat-company-to-boatmen + delay-tugboat-company-response-to-boatmen))

set paid-delay-costs-boatmen (chargeable-waiting-costs-terminal-to-boatmen * (delay-boatmen-to-terminal + delay-boatmen-response-to-terminal) +
chargeable-waiting-costs-shipping-company-to-boatmen * (delay-boatmen-to-shipping-company + delay-boatmen-response-to-shipping-company) +
chargeable-waiting-costs-port-authority-to-boatmen * (delay-boatmen-to-port-authority) +
chargeable-waiting-costs-pilot-to-boatmen * (delay-boatmen-to-pilot + delay-boatmen-response-to-pilot) +
chargeable-waiting-costs-tugboat-company-to-boatmen * (delay-boatmen-to-tugboat-company + delay-boatmen-response-to-tugboat-company))

;; player charge waiting cost if they are delayed in some cases. Player do not compensate themself
;; players are not compensated if they are experience time gains.

set received-delay-costs-terminal (chargeable-waiting-costs-terminal-to-shipping-company * delay-shipping-company-to-terminal +
chargeable-waiting-costs-terminal-to-shipping-agent * delay-shipping-agent-to-terminal +
chargeable-waiting-costs-terminal-to-port-authority * delay-port-authority-to-terminal +
chargeable-waiting-costs-terminal-to-pilot * (delay-pilot-to-terminal + delay-pilot-response-to-terminal) + chargeable-waiting-costs-terminal-to-tugboat-company * ;; account for nautical service providers having two delay functions
(delay-tugboat-company-to-terminal + delay-tugboat-company-response-to-terminal) + chargeable-waiting-costs-terminal-to-boatmen * (delay-boatmen-to-terminal + delay-boatmen-response-to-terminal))

set received-delay-costs-shipping-company (chargeable-waiting-costs-shipping-company-to-terminal * delay-terminal-to-shipping-company +

set received-delay-costs-shipping-agent (chargeable-waiting-costs-shipping-agent-to-terminal * delay-terminal-to-shipping-agent +

set received-delay-costs-port-authority (chargeable-waiting-costs-port-authority-to-terminal * delay-terminal-to-port-authority + chargeable-waiting-costs-port-authority-to-shipping-company *
delay-shipping-company-to-port-authority + chargeable-waiting-costs-port-authority-to-shipping-agent * delay-shipping-agent-to-port-authority +

set received-delay-costs-pilot (chargeable-waiting-costs-pilot-to-terminal * delay-terminal-to-pilot + chargeable-waiting-costs-pilot-to-shipping-company *
delay-shipping-company-to-pilot + chargeable-waiting-costs-pilot-to-shipping-agent * delay-shipping-agent-to-pilot +
chargeable-waiting-costs-pilot-to-port-authority + delay-port-authority-to-pilot +
chargeable-waiting-costs-pilot-to-tugboat-company *

set received-delay-costs-tugboat-company (chargeable-waiting-costs-tugboat-company-to-terminal * delay-terminal-to-tugboat-company + chargeable-waiting-costs-tugboat-company-to-shipping-company *
chargeable-waiting-costs-tugboat-company-to-port-authority + delay-port-authority-to-tugboat-company + chargeable-waiting-costs-tugboat-company-to-pilot *

set received-delay-costs-tugboat-company (chargeable-waiting-costs-tugboat-company-to-terminal * delay-terminal-to-tugboat-company + chargeable-waiting-costs-tugboat-company-to-shipping-company *
(delay-pilot-to-tugboat-company + delay-pilot-response-to-tugboat-company) +
chargeable-waiting-costs-tugboat-company-to-boatmen * (delay-boatmen-to-tugboat-
company + delay-boatmen-response-to-tugboat-company))

set received-delay-costs-boatmen (chargeable-waiting-costs-boatmen-to-terminal *
delay-terminal-to-boatmen + chargeable-waiting-costs-boatmen-to-shipping-company *
delay-shipping-company-to-boatmen + chargeable-waiting-costs-boatmen-to-
shipping-agent * delay-shipping-agent-to-boatmen +
chargeable-waiting-costs-boatmen-to-port-authority * delay-port-authority-to-
boatmen + chargeable-waiting-costs-boatmen-to-pilot *
(delay-pilot-to-boatmen + delay-pilot-response-to-boatmen) + chargeable-waiting-
costs-boatmen-to-tugboat-company * (delay-tugboat-company-to-boatmen + delay-
tugboat-company-response-to-tugboat-company))

set experienced-costs-terminal (total-delay-terminal * cost-of-hour-delay-terminal -
received-delay-costs-terminal + paid-delay-costs-terminal)
set experienced-costs-shipping-company (total-delay-shipping-company * cost-of-
hour-delay-shipping-company - received-delay-costs-shipping-company + paid-delay-costs-
shipping-company)
set experienced-costs-shipping-agent (total-delay-shipping-agent * cost-of-hour-
delay-shipping-agent - received-delay-costs-shipping-agent + paid-delay-costs-shipping-
agent)
set experienced-costs-port-authority (total-delay-port-authority * cost-of-hour-
delay-port-authority - received-delay-costs-port-authority + paid-delay-costs-port-
authority)
set experienced-costs-pilot (total-delay-pilot * cost-of-hour-delay-pilot - received-
delay-costs-pilot + paid-delay-costs-pilot)
set experienced-costs-tugboat-company (total-delay-tugboat-company * cost-of-
hour-delay-tugboat-company - received-delay-costs-tugboat-company + paid-delay-costs-
tugboat-company)
set experienced-costs-boatmen (total-delay-boatmen * cost-of-hour-delay-
boatmen - received-delay-costs-boatmen + paid-delay-costs-boatmen)
set experienced-costs-system (experienced-costs-terminal + experienced-costs-
shipping-company + experienced-costs-shipping-agent + experienced-costs-port-authority +
experienced-costs-pilot + experienced-costs-tugboat-company + experienced-costs-
boatmen)

tick
done

**EXPERIMENTAL DESIGN**

For the experiment described in paragraph 5.2.3 the variables varied (including the values
attained) are the following:

- "ship-size" 1500 16000
- "decision-terminal" -0.5 0 0.5
- "decision-shipping-company" -0.5 0 0.5
- "decision-shipping-agent" 0
- "decision-port-authority" 0 0.5
- "decision-pilot" 0 0.5
- "decision-tugboat-company" 0 0.5
Next to these varied variables, the simulation model reports the following variables for each run;

Measured variables / reporters:
departure-time
ETD-by-terminal
ETD-by-shipping-company
desired-ETD
feasible-ETD-port-authority
feasible-ETD-pilot
feasible-ETD-tugboat-company
feasible-ETD-boatmen
response-time-pilot
response-time-tugboat-company
response-time-boatmen
total-delay-terminal
total-delay-shipping-company
total-delay-shipping-agent
total-delay-port-authority
total-delay-pilot
total-delay-tugboat-company
total-delay-boatmen
total-delay-system
experienced-costs-terminal
experienced-costs-shipping-company
experienced-costs-shipping-agent
experienced-costs-port-authority
experienced-costs-pilot
experienced-costs-tugboat-company
experienced-costs-boatmen
experienced-costs-system
APPENDIX H: SIMULATION MODEL RESULTS

This appendix shows the graphs related to the ‘base case’ analysis. That is, the graphs showing the influence of the actions of players without an input scenario. An online appendix contains the spreadsheets in which all relevant graphs and tables can be generated as well as the netlogo models used to generate the data. To access the online appendix, use the following link:
https://www.dropbox.com/sh/14952ceuk1tyoge/AAA6kHNxx8KreVXXZJIAp1a?dl=0

Figure 38: Influence of Port Authority’s choice

Figure 39: Influence of Pilot’s choice
Figure 40: Influence of Tugboat company’s choice

Figure 41: Influence of Pilot’s second choice
Figure 42: Influence of Tugboat Company’s second choice