

A resilient strategy roadmap for the Harbourmaster in an uncertain environment of the port-call-process

A qualitative application of the Dynamic Adaptive Policy Pathways framework



MSc Thesis

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Pathways framework

by

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SUMMARY

1. RESEARCH CONTEXT

The Port of Rotterdam (PoR) is the twelfth largest port in the world and in terms of port planning and development considered as a leading port (IAPH, 2017; Notteboom et al., 2015). Shipping companies select a port based on the optimal deployment of their fleet and therefore the level of efficiency in the PoR is essential in order to maintain this position (EY Parthenon, 2018). Considering the Port's complex planning processes with many organisations, this efficiency lies in all processes and actions involved with the completion of vessel calls (the port-call-process). In order to maintain competitive advantage, ports now must adapt effective strategies to deal with the fast change in their environment (Cheon et al., 2018).

High quality port operations increase efficiency in the port-call-process and therefore reduce the average time a vessel has to stay in the port (Ducruet et al., 2014; Moon & Woo, 2014). The Harbourmaster (HM) is responsible for a safe and smooth flow of the port-calls in the Port of Rotterdam (Havenbedrijf Rotterdam, 2016a). Efficient and safe management of vessel traffic plays a key role in determining the turnaround time of a vessel and therefore the contribution of the Harbourmaster to an efficient port-call-process is an important factor in the competitiveness of ports.

New disruptive applications of ICT innovations such as digitalisation and automation, come along with opportunities contributing to high quality port operations. On the other hand, they lead to unexpected changes and threats that are not identified for the Harbourmaster yet and might cause a decrease in efficiency and safety in the port-call-process. To maintain competitive advantage, the need for strategies to respond to these uncertainties has become paramount.

2. RESEARCH OBJECTIVES

Digitalisation and automation is a wide spread trend and organisations, including ports, must define a strategy to respond to this trend. In literature, only the potentials of applications of digitalisation and automation with respect to the entire supply chain or the impact of autonomous vessels on parts of the port-call-process are described (Cappelle, 2017; Chong, 2018; Department for Transport, 2019; Gardeitchik et al., 2019; Schiaretto & Chen, 2017). In addition, a structured approach to investigate the areas of impact of the combination and interaction of digitalisation and automation in an organisation or processes of organisations is lacking. This research therefore aims to alleviate on this gap in research by providing a structured approach to examine the impact of digitalisation and automation in the port-call-process.

A resilient strategy helps the Harbourmaster to adapt, grow and survive in face of changes in the port-call-process due to digitalisation and automation, while guiding decision-making towards the long-term-objectives. A promising method to develop such strategies is the Dynamic Adaptive Policy Pathways (DAPP) framework (Haasnoot et al., 2013; Kwakkel et al., 2010a). However, this quantitative approach has only been applied to deal with impacts of climate change. This research fills the gap in literature by applying the DAPP framework in a qualitative manner to develop a resilient strategy roadmap for the Harbourmaster to manage uncertainties in the port-call-process in an uncertain future.

This research is carried out to help the Harbourmaster to respond and anticipate to the impact of digitalisation and automation in the port-call-process. By doing so, it fills the knowledge gaps on the development of a structured approach to identify the impact of digitalisation and automation in the port-call-process and accordingly the design of a resilient strategy by means of a qualitative application of the DAPP framework. The following research question is formulated to achieve these objectives:

What are resilient strategies for the Harbourmaster to anticipate to the impact of digitalisation and automation of the port-call-process?

3. RESEARCH APPROACH

To provide an answer to the main research question, the DAPP framework is applied in a case study at the Harbourmaster's department as a cornerstone for the development of resilient strategies. Several adjustments to the DAPP framework are required to fit it into this qualitative research.

By taking a deep dive into the organisation of the port-call-process and the Harbourmaster's organisation, the current port-call-process is described and the role of the Harbourmaster in this process is explained. Next, the long-term-objectives of the port-call-process are identified after which the impact of digitalisation and automation on these objectives is assessed. Literature review and interviews with experts serve as a source of information for this first phase of the research.

The conceptualisation of the current system complemented with the identification of the deep uncertainties facing the port-call-process, forms the basis for a scenario-analysis. This results in various possible futures of the port-call-process. These scenarios will evoke challenging questions, opportunities and threats of digitalisation and automation in different circumstances.

To address these threats and seize opportunities, a brainstorm-workshop with employees from the Port-of-Rotterdam is organised to develop effective actions. A qualitative method is applied to sequence the actions and assess their relevance. The final result is a resilient strategy roadmap for the Harbourmaster.

4. MAIN FINDINGS

The port-call-process is divided in six sub-processes (see chapter 3). These are organised by adequate information exchange and a strong collaboration between the Harbourmaster, the Nautical Service Providers (NSP), the terminal, the vessel master and the shipping agent. Data from GPS, Automatic Identification Systems, cameras and (nautical) rules processed via IT-software, but also tacit knowledge serve as important source to make decisions in the port-call-process. The role of the Harbourmaster is to manage vessel traffic by gathering all information and services provided by the organisations and reporting all relevant information with the vessel master and NSP.

The port-call-process is an overarching process involving many organisations that all have their own procedures and interests. Additionally, the port-call-process is influenced by regulations and societal norms. The Harbourmaster has the mandate to facilitate the process and is obliged to report about the performance of the process to the State. For these reasons, defining the objectives of the Harbourmaster for the port-call-process is complex.

By taking into account both the performance indicators that are required to be reported to the State as well as the vision of the Harbourmaster, safety, in terms of number of accidents, and efficiency, in terms of vessel delays, are the most important long-term-objectives that are used as verification of the actions in the resilient strategy roadmap.

Digitalisation and automation have a direct and indirect influence of the port-call-process. Where digitalisation is the transition of analogue data and tacit knowledge to digital information, automation is by means of digitalisation, acquire data and human tacit knowledge so that the system can replace (partially to fully) human labour. These definitions result in the distinction of four levels of impact of digitalisation and automation; in the acquisition of information, the analysis of information, decision-support and decision implementation (see chapter 5). At this moment, a significant part of the port-call-process is analogue and therefore directly affected by digitalisation and automation. An indirect impact can be found in three areas. Firstly it affects the long-term-objectives and challenges the capabilities of the Harbourmaster's organisation to achieve these objectives. Secondly, it affects all six sub-processes of the port-call-process and the applications such as IT infrastructure, sources of information and communication between the organisations. Thirdly, it affects the staff qualifications required to support the port-call-process.

However, the specific impact in the port-call-process, including both opportunities and threats is uncertain. The speed at which developments in technology are applicable and the level of collaboration between organisation are deep uncertainties affecting this impact. Based on these uncertainties, four scenarios are created that evoke challenging questions, threats and opportunities in all areas affected by digitalisation and automation in the port-call-process (see chapter 6).

By means of a brainstorm-workshop with employees from the Port of Rotterdam and after aggregation and specification, thirteen examples of actions are identified that seize opportunities or address problems (see table 1).

Table 1: Effective examples of actions to be used in the resilient strategy roadmap

1. Invest in big data analysis and algorithms	8. Experiment with new technologies
2. Create 'data, systems and security'- department	9. Publish standards used by the Port of Rotterdam
3. Communicate open and transparent	10. Risk management with stakeholders
4. Lobby for applicability of new technologies	11. Involve stakeholders in changes
5. Set requirements for stakeholders	12. Collaborate with other ports
6. Reduction of port-tariff	13. Adjust staff qualifications
7. Get insight in digital competencies	

A qualitative estimation of the sell-by-date and sequence of actions is applied to assemble the pathways for the roadmap (see chapter 8). The resilient strategy roadmap (see figure 1) shows actions that strengthen each other or can extend each others sell-by-dates (vertical lines). As some actions directly affect the objectives of the port-call-process (green pathways), some actions focus on mitigating uncertainties or reducing the chance of failure of other actions by focusing on changes required in the organisation of the Harbour-master (blue pathways) and the required staff qualifications (orange pathway). In order to guarantee for resilience, the two most extreme scenarios are included in the roadmap. This shows that in the 'all hands on deck'-scenario, with a strong collaboration and rapid applicability of technology, actions concerning technology and organisational change are relevant in an earlier stage than in the 'rippling forward' scenario, with a weak collaboration and moderate applicability of technology.

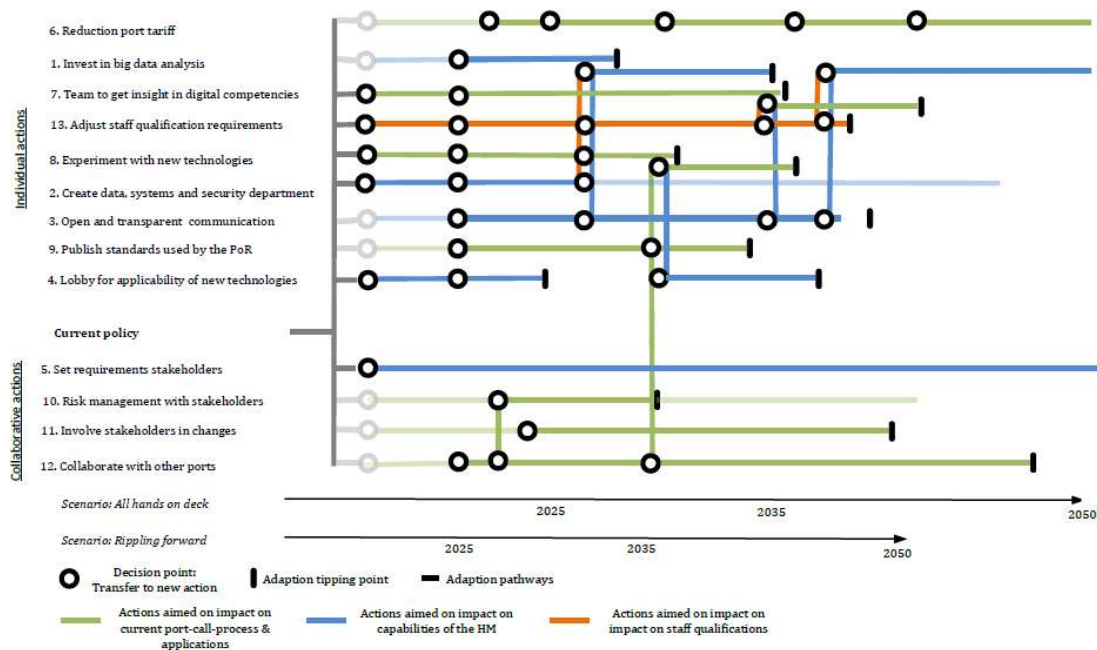


Figure 1: The resilient strategy roadmap

The qualitative application of the DAPP method in this research has appeared to be a suitable method to develop resilient strategies. It has been found that there is not 'only one' resilient strategy for the Harbour-master to anticipate to the impact of digitalisation and automation. An important note therefore is that the resilient strategy roadmap should be interpreted as a guideline and not as a strict set of actions. The contribution lies in the identification of the areas of impact of the actions with respect to the areas of impact of digitalisation and automation in the port-call-process. The Harbourmaster can use the description of actions

and their correlations to identify actions that strengthen each other or mitigate uncertainties. Different combinations of actions result in different resilient strategies. However, it has been found that each combination of actions should include at least one of each type of actions to cover all areas of impact of digitalisation and automation.

During the brainstorm-workshop, interviews and when analysing future scenarios, three main problems were found that should be taken into account in strategic decision-making. Firstly, the conversion of tacit knowledge to digital data, while maintaining the ability to understand the systems and process to avoid IT dependence. Secondly, digitalisation and automation are expected to cause problems in the harmonisation and security of processes and systems of organisations in the port-call-process, which might result in efficiency decrease. Thirdly, the introduction of autonomous vessels in the port-call-process will be challenging, especially in the transition phase where traditional vessels and autonomous vessels interact. Problems related with safety and efficiency are expected, but also a different role of the Harbourmaster might be required. Recommendations related with amongst others these problems are discussed in the following paragraph.

5. RECOMMENDATIONS

This research is built on several assumptions and limitations that lead to opportunities to conduct further research. Although the scenarios in this research have been verified by experts from different departments, it is recommended to establish scenarios in a group setting rather than on individual basis. This might result in an increase in organisational support or could lead to different scenarios and subsequently different actions to be used for the resilient strategies. In addition, to obtain a wider set of more valid, specific and consistent actions, it is recommended for future researches including a brainstorm-workshop, to reserve more time and to include a higher amount of participants stemming from different organisations. Lastly, the assembling of pathways in this research was done qualitatively, based on the sell-by-dates and relevance. In case other factors were taken into account, such as risks, costs, or availability of resources, other sequences of actions might be found. When a different research applies the DAPP in a qualitative manner, it is recommended to investigate what factors are most suitable to use in that case.

The findings of this research lead to two important recommendations for further research. While literature shows that autonomous vessels are expected to have a radical impact on the port-call-process, during the brainstorm-workshop no problems were identified on this field and subsequently this aspect is not taken into account in the design of the resilient strategy roadmap. From interviews and literature study, there is no doubt that (variants) of autonomous vessels will be introduced within thirty years from now, resulting in major consequences in the transition phase where autonomous and conventional vessels interact. It is strongly recommended to investigate this further including aspects such as the impact on safety, efficiency and the changing role of organisations in the port-call-process. In addition, it was found that great improvements are to be made in the field of planning of vessels and NSP when terminal planning is included, resulting in synchronodal or Just-In-Time transport. Since this aspect was not included in the scope of this research it has not been taken into account. Therefore it is recommended to conduct further research to the opportunities of digitalisation and automation concerning the planning of terminals.

These limitations however, do not refute the fact that still some important insights can be inferred for the Harbourmaster. During interviews and the brainstorm-workshop, collaboration with organisations in the port-call-process was perceived essential for the well-performance of the port-call-process. Suggested is to focus on actions that improve the relation between these organisations. Moreover, it is recommended to collaborate with knowledge institutes and other departments in the Port of Rotterdam to stimulate development and applicability of technologies and seize the corresponding opportunities. Furthermore, tacit knowledge is appeared to be an essential source of information in the Harbourmaster's organisation and therefore it is recommended to carefully choose when this type of knowledge can opt for digitalisation and automation and in what circumstances the human factor should remain.

Finally, these managerial recommendations are suggested to be included in the Harbourmaster Next Generation Programme. The scenarios should be used to raise awareness and the three main problem are suggested to be a guideline within all facets of this programme.

PREFACE

In front of you lies my master thesis as the final deliverable of the MSc Transport, Infrastructure and Logistics at Delft University of Technology and the end of my student life in Delft.

My interests in water, ports, vessels, and logistics have led me to the Harbourmaster's department of the Port of Rotterdam where I conducted my research. Half a year ago, I was uncertain about the final deliverable and aims of this research. Step by step, I got more acquainted with digitalisation and automation and their impact on organisations, with doing scientific research and the ups and downs accompanying it, and above all with the complex processes in the port and Harbourmaster's department. By combining various methods, skills, tools, and theories that I have learned and acquainted myself with during both my Bachelor and Master, I can say I have contributed to the scientific world as well as to the knowledge in the Harbourmaster's organisation and I am proud of the final result.

This report would not exist without the help from others and I would like to take the opportunity to thank everyone that has contributed to the completion of my master. First of all I would like to sincerely thank my graduation committee for all their help throughout this process. I would like to thank Lori for listening to my complicated requirements for the graduation topic I had in mind and linking me to the Port of Rotterdam. I would like to thank Winnie for the two-weekly meetings where you always provided me with critical notes, advice and tips to get the best out of this thesis. Bert, I would like to thank you for the help with the scenario-analysis, brainstorm-workshop and the interpretation of the DAPP-method. You all have given me very clear guidance through sharp criticism, constructive comments and personal support.

Then I would like to thank my colleagues at the Harbourmaster's department. They have been open and welcoming from the beginning, including me in their work environment. Partly because of them, I have had a useful, but above all very pleasant internship period. A special thanks to Raymond, who always took time to help me. Thanks for the extensive answers to my questions, for the sharp comments on my formulation, for setting up the interviews and for enlightening me with 'de Wetten van Seignette'.

Last but certainly not least, I would like to thank my friends and family. My family, pap, mam and Jop, who have always stimulated me to keep my head up in case of disappointments and reminded me to enjoy this period by seizing all opportunities that came on my path. Even though this resulted in quite a long period of "studying". I would like to thank my friends and roommates, for their daily motivational talks, and for fulfilling the role of wailing wall. I am glad we could perform this role for each other simultaneously. And a special thanks to Frits for always supporting me and being there for me during the ups and downs of the past six months.

My period as a TU Delft-student has been an interesting, exciting, challenging and an amazing one. With several committees, internships and lots of travels and projects abroad I can definitely say I got the most out of it. I am convinced that all lessons that I have learned throughout my TU Delft-period will be of great use for the rest of my life.

*Door van der Wiel
Delft, April 2019*

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ABBREVIATIONS

General

APP	Adaptive Port Planning
AP	Adaptive Pathways
APM	Adaptive Policy Making
ATA	Actual Time of Arrival
AV	Autonomous Vessel
DAPP	Dynamic Adaptive Policy Pathways
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
KPI	Key Performance Indicator
NOA	Notion of Arrival
PV	Patrol Vessel
TRL	Technology Readiness Level
VHF	Very High Frequency
VTM	Vessel Traffic Management

Organisations

HM	Harbourmaster
HMNG	Harbourmaster Next Generation
HCC	Harbour Coordination Centre
IMO	International Maritime Organisation
KVRE	Koninklijke Vereeniging Roeiers Eendracht
NSP	Nautical Service Providers
PA	Port Authority
PoR	Port of Rotterdam
SCC	Shore Control Centre
VTs	Vessel Traffic Service

DEFINITIONS

Automation	By means of digitalisation, acquire data and human tacit knowledge so that the system can replace (partially to fully) human labour.
Digitalisation	The transition from analogue to digital information services in combination with the development and implementation of sensors, equipment and data sharing in order to improve business
Process	The path of work that "crosses" several functions, plus the architecture that connects the relevant activities, people, information systems, and other resources along that path (Damelio, 2011).
Port-call-process	The processes and actions involved with the completion of vessels between the first notion of an arriving vessel and the moment of the last contact.
Port infrastructure	The basic civil infrastructure (channels, basins, quay walls, etc.), the superstructure, the equipment and the operational infrastructure needed to facilitate the port-call-process.
Resilient strategy	a strategy that helps the organisation to survive, adapt and grow in face of changes in its environment, while guiding decision making towards long-term-goals
Smart Ships	Further development of traditional ships, with a number of sustaining innovations, which constitute together an (autonomous) vessel,
Vessel Traffic Management	The management of all services and reliable information needed by the interacting organisations in the port-call-process in order to enhance safety and efficiency

INTRODUCTION

The Port of Rotterdam (PoR) is the twelfth largest port in the world and the largest port of Europe in terms of cargo tonnage and container traffic (IAPH, 2017; Notteboom et al., 2015). Furthermore, in terms of port planning and port development, the PoR is globally considered as a leading port (Notteboom et al., 2015). Over the past decade, a number of regulatory and technical changes have caused unstable and contested business landscapes in the port sector. For shipping companies, the optimum deployment of their fleet plays a key role in their selection of a specific port (Port of Rotterdam, 2014). This optimum depends on the level of efficiency of a port. Considering the Port's complex planning processes with many organisations, this efficiency lies in all processes and actions involved with the completion of vessel calls. A reduced efficiency in this so-called port-call-process, therefore may on its turn decrease the competitive advantage of the PoR (EY Parthenon, 2018). In order to maintain a competitive advantage, ports now must adapt effective strategies and operations, to deal with the fast change in their environment (Cheon et al., 2018).

An efficient port-call-process depends on the average time that a vessel stays in a port before departing to another port. This is the difference between time of entrance and time of departure (Ducruet et al., 2014). High-quality port operations can lead to a reduction in port time for vessels (Moon & Woo, 2014). The Harbourmaster (HM) is responsible for a safe and smooth flow of the port-calls in the Port of Rotterdam (Havenbedrijf Rotterdam, 2016a). Efficient and safe management of vessel traffic plays a key role in determining the turnaround time of a vessel and therefore is an important factor in the competitiveness of ports.

New disruptive ICT innovations such as digitalisation and automation, can contribute to high quality port operations and will bring substantial changes to the current port-call-processes. Besides this, the continuous trend in larger ships as well as increasing cost of labour, will push the need and desire for automation and make it become more widespread (Taneja et al., 2010). Traffic operations are further optimised in real time by technologies such as intelligent software and sensors which cause a reduction on the pressure in the Port but at the same time results in a future the Harbourmaster cannot predict. Both threats and opportunities of this trend with respect to the port-call-process are not identified for the Harbourmaster yet. On the other hand, the question raises to what extent the Harbourmaster is responsible for facilitating in the opportunities and preventing the port-call-process from threats, while guaranteeing safety and a fast completion of vessel traffic.

1.1. PORT OF ROTTERDAM AND HARBOURMASTER

The Port of Rotterdam manages, operates and develops the port and industrial area of Rotterdam. It has a strong focus on digitalisation in order to create a more efficient port and trade of goods. By doing so, they contribute to their vision of strengthening the international competitive position of the port as a logistic node and industrial area in the world (Port of Rotterdam, 2014; Rotterdam Jaarverslag, 2017). The Harbourmaster's division, as part of the organisation, is contributing to this vision by maintaining a safe and efficient handling of all shipping (Rotterdam Jaarverslag, 2017). The organisational structure of the PoR is presented in figure 1.1.

The (State) Harbourmaster division performs public duties such as traffic guidance, inspection and inci-

dent control and is responsible for a safe, efficient and sustainable completion of navigation (Havenbedrijf Rotterdam, 2016a). To be able to perform this duty, the Harbourmaster has the mandate to perform certain public-law tasks (Ministerie van Verkeer en Waterstaat, 2004). To the aim of facilitating safe and efficient vessel traffic management, the HM cooperates with pilots, towing services, boatman, terminals and other partners in the port. Vessel traffic management (VTM) in this research is defined as the management of all services and reliable information needed by the interacting organisations in the port-call-process in order to enhance safety and efficiency. As can be seen in figure 1.1, the Harbourmaster's division consists of six departments, all collaborating in the port-call-process in order to manage the vessel traffic (Havenbedrijf Rotterdam, 2016a):

- **Harbour Coordination Centre (HCC):** the Harbour Coordination Centre controls planning and access of vessels and deals with administrative clearances.
- **Vessel Traffic Service (VTS):** the VTS operators monitor and deal with operational clearances of all vessels which enter and leave the PoR.
- **Harbour patrol boats:** the patrol boats are responsible for inspection, incident response and law enforcement on the water.
- **Inspection:** in this department vessels get checked with the shipping regulations concerning environment and safety.
- **Port Health Authority:** the Harbourmaster is a member of the Port Health Authority. In the event of epidemics on board, the Port Health Authority advises and guides vessels.
- **Port Security:** the HM is the authority for security in the entire port on behalf of the Mayor of Rotterdam. Security roles set by the International Maritime Organisation (IMO) in the International Ship and Port facility Security Code (ISPS) apply in the PoR.

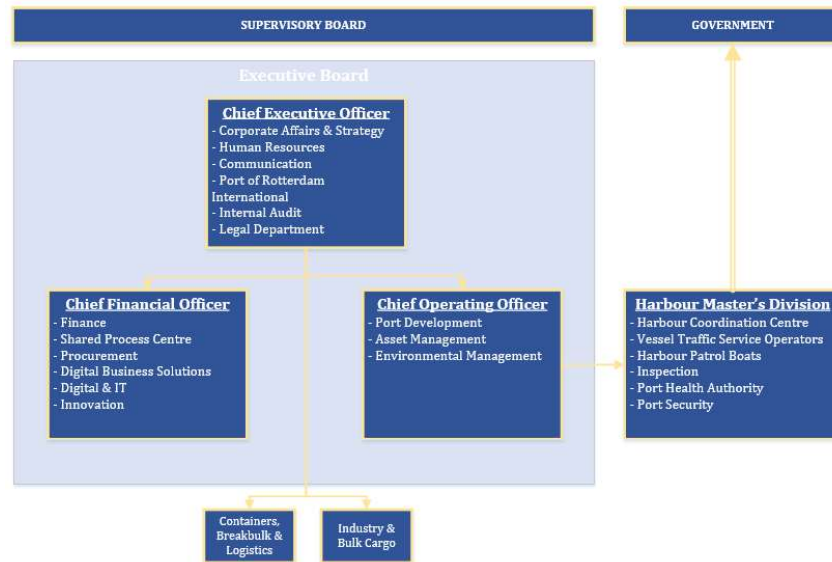


Figure 1.1: Organisational structure of the Port of Rotterdam

1.2. PROBLEM STATEMENT

In this section the problem that is addressed in this research is described by first elaborating on the gaps in literature. Subsequently the research objectives are presented followed by the research questions.

1.2.1. GAPS IN LITERATURE

Digitalisation and automation is becoming widespread in many organisations all over the world. Ports are facing this trend as well and must define a strategy to react to this trend. The need for managing vessel traffic in the port-call-process might change, together with the role and responsibilities of the Harbourmaster in this process. To the best of the authors knowledge, until now, no attention has been paid in literature to the assessment of the impact of digitalisation and automation in the port-call-process. The potentials of some of the applications of digitalisation and automation with respect to part of processes of organisations is described. In the maritime sector, this comes down to implications of the trend for the entire supply chain or the introduction of autonomous vessels on parts of the port-call-process (Cappelle, 2017; Chong, 2018; Department for Transport, 2019; Gardeitchik et al., 2019; Schiaretti & Chen, 2017). However, a structured approach to investigate the areas of impact of the combination of digitalisation and automation in an organisation or processes of organisations is lacking. This research therefore aims to alleviate on this gap in research by providing a structured approach to examine the impact of digitalisation and automation in the port-call-process.

Secondly, planning and decision-making approaches for the Harbourmaster to anticipate to the impact of digitalisation and automation are required. Several sources describe empirical studies concerning adaptive planning. The most promising are the Dynamic Adaptive Policy Pathway (DAPP) framework and the Adaptive Port Planning (APP) approach. The DAPP approach is introduced by Kwakkel and Haasnoot and aims to support the development of an adaptive plan that is able to deal with conditions of deep uncertainties (Haasnoot et al., 2013). With the help of adaption pathways, the decision-maker is guided towards the long-term-objectives in a system exposed to a changing environment. However, this framework was created and has only been used to design a dynamic adaptive plan to deal with deep uncertainties associated with global climate change (Haasnoot et al., 2013; Kwakkel et al., 2016). For port planning and roadmapping in uncertain situations, the APP framework has been introduced by Taneja et al. in 2011. It uses various real options to deal with future demand and new technologies in ports. The approach is introduced to recognise uncertainties in a plan and to incorporate strategies for dealing with them (Taneja et al., 2011). Nevertheless, the APP approach has mostly been used to seek options when decisions have to be made concerning investments in port civil infrastructure (mooring dolphins, quay walls, breakwaters, etc.) (Azizi, 2014; Taneja et al., 2011). For issues concerning uncertainties in technology developments and their impacts on managing vessel traffic in the port-call-process, the framework has not been applied yet. Besides this, the framework has not been tested whether or not it can guide to design suitable strategies for the Harbourmaster to manage the changes. Therefore this research aims to fill this gap in literature by developing a strategy roadmap for the Harbourmaster to manage uncertainties in the port-call-process due to changes in the environment.

1.2.2. RESEARCH OBJECTIVES AND QUESTIONS

This research is carried out to help the Harbourmaster to respond and anticipate to the impact of digitalisation and automation in the port-call-process. By doing so, it fills the knowledge gaps on the development of a structured approach to identify the impact of digitalisation and automation in the port-call-process and to develop a strategy roadmap to manage uncertainties in the port-call-process due to changes in the environment. To answer these gaps, this research firstly conceptualises the current port-call-process, the objectives as well as the trend of digitalisation and automation. Secondly, uncertainties that come along with this trend are examined in order for the Harbourmaster to understand scenarios that might affect his business. Finally a concrete roadmap with resilient strategies is developed to act upon the scenarios to give a full profile of the options the Harbourmaster has to manage the port-call-process.

1.2.3. MAIN RESEARCH QUESTION

In a changing and uncertain environment for the Harbourmaster, the need for exploring future scenarios and ways the Harbourmaster can anticipate to trends is huge. The gaps in literature and the research objectives imply the following research question:

What are resilient strategies for the Harbourmaster to anticipate to the impact of digitalisation and automation of the port-call-process?

A resilient strategy is a strategy helping the organisation to survive, adapt and grow in face of changes in its environment, while guiding decision making towards long-term-goals. These strategies will be devel-

oped using the Dynamic Adaptive Policy Pathways framework resulting in a resilient strategy roadmap for the Harbourmaster.

1.2.4. SUB-QUESTIONS

The sub-questions help in answering the main question and serve as a path to the desired results. They relate to the knowledge gaps and research objectives and structure the research. The sub-questions have been set up in such a way that they represent the conceptual model of the Dynamic Adaptive Policy Pathways framework that is used in this research (see chapter 2).

1. *How is the port-call-process currently organised?*
2. *What are the objectives of the Harbourmaster for the port-call-process?*
3. *How do the trends of digitalisation and automation affect the current port-call-process?*
4. *How can future scenarios contribute to a resilient strategy for the Harbourmaster in order to anticipate to digitalisation and automation in the port-call-process?*
5. *What are effective actions the Harbourmaster can undertake to anticipate to the impact of the scenarios?*
6. *How does the resilient strategy roadmap for the Harbourmaster look?*

1.3. RELEVANCE

The relevance of this research can be divided in a societal and a scientific point of view.

From a scientific point of view, this research will conceivably make a significant contribution to the existing literature by alleviating on the research gaps. A structured approach to identify impacts of digitalisation and automation in an organisation, especially in a port related environment, has not been proposed in literature up until now. In addition, this research will provide a more holistic approach on adaptive decision making based on scenarios in ports with the aim of designing a resilient strategy. This contribution is specifically aimed at the port-call-process in the Port of Rotterdam in an uncertain future due to digitalisation and automation. Scientific literature is currently lacking given that most empirical research evaluates only decision pathways in an infrastructural or environmental perspective (Haasnoot et al., 2013; Mansouri et al., 2010; Taneja et al., 2011). Knowledge on change- and risk management in a complex port environment exposed to uncertain futures due to digitalisation and automation could serve for future simulation studies that could provide more effects such as emission reduction or a potential shift in the supply chain.

From a societal point of view, this research contributes to the knowledge of actions the Harbourmaster can undertake to manage uncertainties affecting his operations. Digitalisation and automation affect processes, roles and responsibilities of many companies. The Port of Rotterdam, being a major logistic hub operating in a dynamic environment with many stakeholders and serving as a prominent driver of the Dutch economy, therefore is a highly interesting company to look at when such innovations take place (Bosch & Hollen, 2015). The Harbourmaster has to deal with a large amount of stakeholders with all different objectives and tools who act on their own interests. The system consists of exceptions which makes it hard to automate, especially in an uncertain environment. It is therefore of great importance that vessel traffic management in the port keeps up with the developments regarding digitalisation and automation. If not, consequences can be found in for instance collisions and inefficient vessel traffic management leading to a reduced competitive position.

1.4. SCOPE

This research is focused on the digitalisation and automation of the port-call-process in the Port of Rotterdam. Only the traffic of deep-sea-vessels is included. The geographic area the Harbourmaster manages (facilitates, guides, maintains) differs per area but lies within the area between the Brienenoordbrug, Spijkenis-serbrug and the 12-mile-line.

Both international and national laws concerning digitalisation and automation in ports are being developed. Within this research, the assumption is that scenarios and strategies to act upon the scenarios are legitimate according to the law-to-be.

The impact of digitalisation and automation on the port-call-process is analysed in terms of impact on the

organisation and on the long-term-objectives of the port-call-process and Harbourmaster. This implies the impact on other aspects such as costs, environment or trade has not been taken into account. To remain consistent these aspects are out of the scope as well when designing actions to be used in the resilient strategy roadmap. In addition, this research is a qualitative research meaning the impact is based on literature, interviews and causal relations and not on quantitative data.

Digitalisation and automation in a port environment is developing quicker then ever and urges the Harbourmaster to manage it. Due to the complex environment, changes might take a long time to be implemented. To combine the fast development of technologies and complex, slowly changing environment, the time span that will be looked at within this research is thirty years from now.

When designing actions, the Harbourmaster is perceived to be one stakeholder. In reality, the Harbourmaster's organisation consists of various departments all having their own responsibilities. Furthermore, only actions the Harbourmaster can implement to anticipate to the scenarios will be analysed. Actions to be executed by other departments at the Port of Rotterdam are not part of this research.

1.5. THESIS OUTLINE

The remainder of this research is visualised in the research flow diagram in figure 1.2 and is substantiated as follows: the second chapter will elaborate on the theoretical framework used in this case study at the Harbourmaster's department to design resilient strategies for the Harbourmaster to anticipate to changes in the port-call-process due to digitalisation and automation. The conceptualisation phase will first alleviate on the current port-call-process and will lead to a detailed process map (chapter 3). In chapter 4 the long-term-objectives of the port-call-process are discussed after which in chapter 5 the areas of the port-call-process that are affected by digitalisation and automation are described. In the analysis phase, chapter six describes possible futures in a changing environment that evoke problems or opportunities of digitalisation and automation in the port-call-process. In the design phase, actions for the Harbourmaster will be identified to seize opportunities and avoid or overcome these problems (chapter 7) after which the resilient strategy roadmap will be developed (chapter 8). Finally in the conclusion the outcomes of the research will be discussed and the contribution of this research is presented.

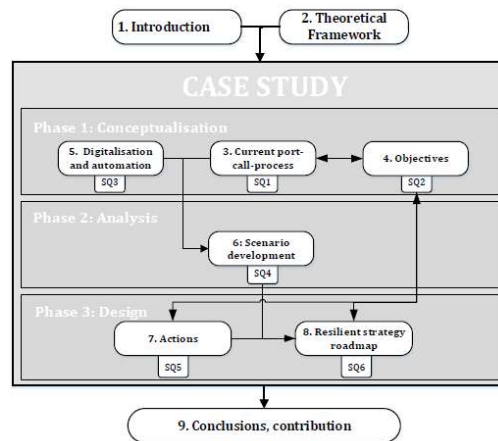


Figure 1.2: Research flow diagram

2

THEORETICAL FRAMEWORK

The theoretical framework is used to set up the research methodology that is applied within this case study at the Harbourmaster's division. As stated in the section 1.2, there is no suitable method supporting strategic decision-making in the port-call-process exposed to uncertainties in the environment. One of the methods described in literature on planning under uncertainty is the Dynamic Adaptive Policy Pathways (DAPP) framework. The case study method is used to test whether or not the DAPP framework can be applied to design resilient strategies for the Harbourmaster in the port-call-process in an uncertain environment due to digitalisation and automation. By doing so, this research provides an answer to the main question 'What are resilient strategies for the Harbourmaster to anticipate to the impact of digitalisation and automation of the port-call-process?'.

In section 2.1 the application of the DAPP framework to design resilient strategies within this research is discussed. Adaptions need to be made to this framework in order to cover the knowledge gaps as well as to provide a method to answer the main research question. In section 2.2 the case study method is discussed and the methods used within this case study are elaborated upon.

2.1. THEORETICAL BASE

An important part of the research objective is to contribute (scientifically) to the existing knowledge of decision-making in an uncertain environment in the port-call-process. This research tests whether the DAPP framework is a suitable method to design strategies for the Harbourmaster to anticipate to digitalisation and automation in the port-call-process. Since the deliverable of this research is a set of resilient strategies to respond to digitalisation and automation in the port-call-process, the concept 'resilient strategy', is essential. This section therefore first elaborates on the characteristics of a resilient strategy. Next the DAPP method will be explained and the adaptations that are made to fit the DAPP framework in this research.

2.1.1. RESILIENT STRATEGIES

Managing risks of an uncertain future is a challenge that requires resilience. Resilient capability is vital for organisations and a key to competency since it enables improvements in system performance and decreases vulnerabilities (Pettit et al., 2010; Vugrin et al., 2011). With this capability, organisations are agile enough to respond to developments, while still pursuing a strategy that guides decision making towards long term goals within the boundaries of their fundamental values (Lenssen, 2014). Resilient strategies can offer a perspective of the business and on the same time identify the direction in which the organisation should move when disruptive trends are affecting the company and its markets.

Resilience has been defined by a number of authors in a related manner. Vugrin et al. (2011) highlight that resilience is the ability of a system to respond to a 'disruption' due to an event or set of events. A similar conclusion is reached by Holling, including that a resilient system maintains its functions and controls when exposed to a disruption (Holling, 1973). Pettit et al. and Walker define resilience as not only to be able to respond to a disruption, but also to survive and grow in the face of this change (Pettit et al., 2010; Walker et al., 2001). Lenssen highlights the importance of acceptance of the strategy by the organisation. He mentions that a resilient strategy is based on an understanding throughout the company of the potential for success, stem-

ming from the societal context in which the business interacts and operates (Lenssen, 2014). Various other authors argue as well that for any organisation in order to survive and succeed in a continuously evolving environment, adequate change management with respect to the employees is required for successful implementation of new strategies (By, 2005; Oke, 2007; Waddell & Sohal, 1998).

Based on the above, a resilient strategy in this report is defined as '*a strategy that helps the organisation to survive, adapt and grow in face of changes in its environment, while guiding decision making towards long-term-goals*'. Characteristics of a resilient strategy are as follows:

- it helps an organisation to survive, adapt and grow in face of change due to societal developments and trends with an uncertain impact. In this report the main trend analysed is digitalisation and automation in the port-call-process.
- it guides decision making towards long term goals.
- it is desirable by the organisation to implement.

2.1.2. THE DYNAMIC ADAPTIVE POLICY PATHWAY FRAMEWORK

As mentioned in the literature gap section 1.2, a variety of approaches for supporting decision-making under uncertainty has been suggested. This research uses the Dynamic Adaptive Policy Pathways framework, developed by Deltares and the TU Delft (2013). According to Haasnoot, 'decision makers facing a highly uncertain future need more than traditional prediction or scenario-based decision methods to help them to evaluate alternatives and make decisions' (Haasnoot et al., 2013). Dynamic adaptive plans are needed to develop plans in deep uncertain environments (Haasnoot et al., 2013; Kwakkel et al., 2016). A pathway roadmap can be used to illustrate the sequence of action plans to be taken (Phaal & Muller, 2009).

The DAPP framework combines two bodies of literature on adaptive planning under uncertainty: Adaption Pathways (AP) and Adaptive Policy Making (APM), both illustrated in figure 2.1. Both of these methods aim on designing adaptive policies in an uncertain environment, which is an essential characteristic of a resilient strategy.

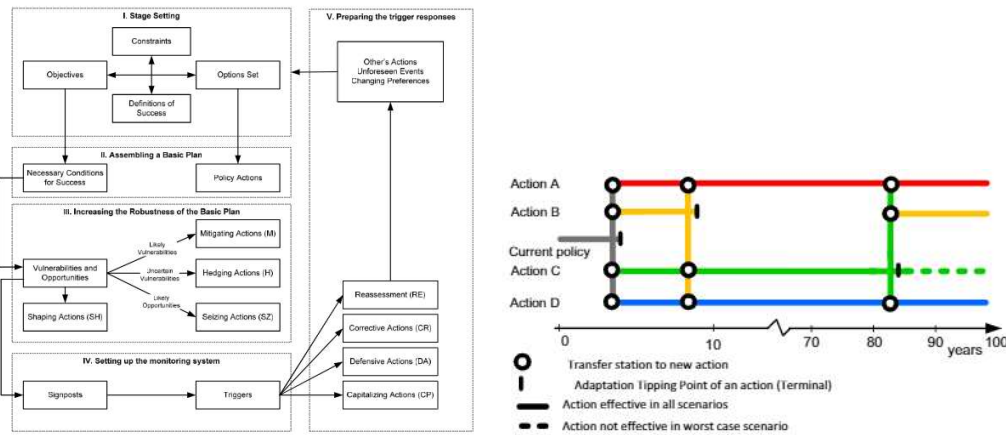


Figure 2.1: Adaptive Policy Making (left) and Adaption Pathways (right) (Haasnoot et al., 2013)

ADAPTIVE POLICY MAKING

The Adaptive Policy Making approach is developed to support the implementation of long-term plans despite the presence of uncertainties (Walker et al., 2013). It is a structured approach for designing dynamic robust plans (Kwakkel et al., 2010b). In the first step, the current system is described including objectives for future development. The second step includes the basic plan that can be executed to reach these goals. The third step defines four types of actions: mitigating actions are actions to reduce the likely adverse effects of a plan; hedging actions ought to spread or reduce the uncertain adverse effects of a plan; seizing actions to

seize likely available opportunities and shaping actions are taken to reduce failure or enhance success (Haasnoot et al., 2013; Walker et al., 2013). Signpost are used to track information in order to determine whether the plan is meeting the long-term goals. In case the plan reaches such a signpost, monitoring and corrective actions can contribute to keep the system headed towards long-term goals. This is called contingency planning and contributes to the flexibility and dynamic robustness of the resulting plan (Haasnoot et al., 2013). Four different types of actions can be triggered by a signpost: a re-assessment of the plan when the analysis and assumptions to the plan's success have lost validity, corrective actions to adjust the basic plan, defensive actions to clarify the basic plan and preserve its benefits and capitalising actions to take advantage of opportunities (Dewar et al., 1993; Haasnoot et al., 2013; Kwakkel et al., 2010a). In the APM approach, only one basic plan is developed and no clear guideline in how to reach this plan is defined Haasnoot et al. (2013).

ADAPTION PATHWAYS

Adaption Pathways include the time-component in the development of a plan, which results in a plan that can adapt over time as conditions change (Haasnoot et al., 2013). They present an overview of relevant pathways to get to the same desired point in the future. Adaption Pathways use transient scenarios to consider multiple futures. An essential element in APs are adaption tipping points. An adaption tipping point, specifies the conditions under which a policy action will fail. It is reached when the effect of external changes is such that a policy no longer meets or contributes to its objectives. After this 'sell-by-date', additional actions are needed. Adaption Pathways represent a sequence of possible actions after a tipping point. Unlike the Adaptive Policy Making approach, no specific categorisation of actions is used.

DAPP: THE BEST OF BOTH WORLDS

The Dynamic Adaptive Policy Pathways approach combines the strengths of both approaches. It uses the comprehensive step-wise approach of the APM to identify types of actions to design a plan and the transient scenarios of the Adaption Pathways to explore a wide variety of futures and to sequence the actions.



Figure 2.2: Dynamic Adaptive Policy Pathway framework (Haasnoot et al., 2013)

The DAPP approach starts with a description of the system and the identification of objectives and uncertainties that are relevant for decision-making. The uncertainties are then used to develop plausible futures by means of transient scenarios. These scenarios are compared with the objectives to see if problems arise or opportunities occur. Based on the problems and opportunities, actions are identified. These actions are assessed on their contribution to long-term goals and objectives. This leads to adaption tipping points; just like in the AP approach, these are also a key concept in DAPP. The assessment of the distribution of the timing of adaption tipping points is typically derived from model simulations over transient scenarios (Haasnoot et al., 2013; Kwakkel et al., 2016). This distribution is then summarised in box-whisker plots, and the median or quarter values are used in generating the adaption tipping points. However, the exact timing of the sell-by-date is not important; it should be roughly right (Kwadijk et al., 2010). In addition, the simulations contribute to the robustness of parameters suitable for measuring benefits and disadvantages of actions. At this point, a new action plan is needed. Promising actions are used as the basic building blocks for the assembly of poten-

tial adaption pathways, which is a sequence of actions over time to achieve the objectives under uncertain conditions. This can be presented in an adaption pathways map. The parameters retrieved from simulations can be used in a scorecard that helps in identifying the preferred pathways. Thereby it is used to gain insight into policy options, the sequencing of actions over time, potential lock-ins and path-dependencies.

2.1.3. USING DAPP TO DEVELOP RESILIENT STRATEGIES

In this research, the DAPP framework is used to develop resilient strategies for the Harbourmaster to anticipate to changes in the port-call-process due to digitalisation and automation. A wide variety of relevant uncertainties are explored which contributes to developing strategies that can help the Harbourmaster survive, adapt and grow in face of changes. Furthermore, by constantly monitoring and re-assessing the pathways, the achievement of long-term objectives can be guaranteed. Therefore the DAPP approach seems a suitable method to develop resilient strategies.

Yet, a few adaptations and translations need to be made to fit the DAPP framework in this research in order to achieve the research objectives:

- Haasnoot et al. identify opportunities and threats based on the analysis of reference cases, which is accomplished by using a computational model. In this research the threats and opportunities of digitalisation and automation in an uncertain future are a qualitative interpretation and identified based on the description of the scenarios and complemented by perspectives of employees of the Harbourmaster's division.
- The DAPP framework is used to design relevant actions to deal with problems and seize opportunities in multiple scenarios, to sequence these actions and to monitor the actions by means of adaption tipping points. With its design, the DAPP contributes to the first two characteristics of a resilient strategy as defined in section 2.1.1. In this research the DAPP is adjusted in such a way it also satisfies the third criteria of a resilient strategy; its desirability by the organisation to implement. Therefore, when actions are developed, attention is paid to identify the preferred actions and the preferred scenario within the organisation.
- The DAPP method originally has been used for policy-making for multiple stakeholders among which governmental organisations in order to anticipate to the effects of climate change (Haasnoot et al., 2013). In this research, the DAPP approach serves for one organisation. Only uncertainties in his environment are taken into account. To design a resilient strategy that fits in the Harbourmaster processes, the organisation is involved in the development of strategies. By means of a workshop at the Harbourmaster's department employees have the chance to brainstorm about problems, opportunities and relevant actions to deal with uncertainties. To assess the identified actions based on the long-term objectives of the Harbourmaster, a feedback-loop is included.
- Originally, the DAPP is a quantitative approach. In this case study the adaption tipping points and actions are assessed in a qualitative manner based on the perspectives and preferences from experts from the Harbourmaster's department.
- A pathway as mentioned in the DAPP framework, is based on promising actions to avoid or overcome problems or to seize opportunities in different scenarios. In this research a pathway represents a resilient strategy.

This leads to an adaption of the DAPP research as visualised in figure 2.3. This adapted framework provides the Harbourmaster a guideline to develop resilient strategies to react to the impact of digitalisation and automation in the port-call-process, taken into account uncertainties in his environment.

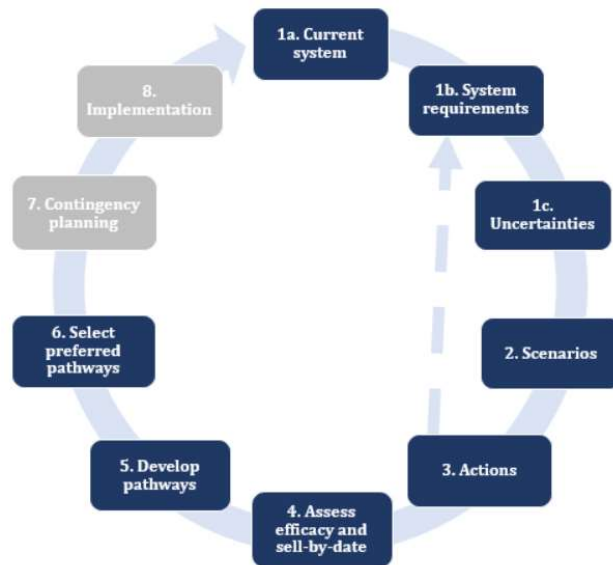


Figure 2.3: Adjusted DAPP framework used in this research

1. The first step is to conceptualise the current system. This step consists of three sub-steps.
 - (a) First the port-call-process is described. This includes all organisations involved in the port-call and the information (infrastructure) supporting this process.
 - (b) Next the long-term-objectives and Key Performance Indicators of the Harbourmaster with respect to the port-call-process are identified. Together these form the system requirements.
 - (c) The third step includes a specification and impact assessment of the major uncertainty that is expected to play a role in decision-making for the Harbourmaster: digitalisation and automation.
2. In the second step, scenarios are established. The specified objectives of step 1b are compared to the possible future situations to identify potential gaps. The major uncertainty identified in step 1c; digitalisation and automation, plays a different role based in each of the scenarios. Both opportunities and threats are considered. Opportunities are developments that can help in achieving the objectives of the Harbourmaster, while threats are developments that can harm the extent to which the objectives can be achieved.
3. Via a brainstorm-workshop with employees from the Port of Rotterdam, actions are identified to act upon the threats and opportunities identified in step 2. These actions are assessed based on the long-term-objectives and aggregated to concrete actions usable for the next steps. The actions can be categorised according to the four types of actions (i.e. mitigating, hedging, seizing and shaping actions). The aim of this step is to assemble a rich set of possible actions.
4. In the fourth step the sequence and the sell-by-dates of all strategies are determined. The sequence is based on the current operations of the Harbourmaster, the starting period and the correlation with other actions. The sell-by-date is based on the contribution to the long-term-objectives and the relevance of the actions. All information needed to establish a pathway roadmap now is available.
5. In the fifth step the resilient strategy roadmap is established. The scenarios, sell-by-dates and sequences are combined to design the pathways.
6. In the sixth step the preferred pathways can be selected based on the preferred role of the Harbourmaster in the port-call-process.

Based on these six steps, the DAPP framework can be used to design resilient strategies. It satisfies all criteria of a resilient strategy since it fits multiple scenarios with different impacts of digitalisation and automation. Actions contributing to long-term-objectives can be designed for the Harbourmaster to survive,

adapt and grow in face of changes in these scenarios. In addition, by actively involving the Harbourmaster's organisation in the development of actions and by specifying the preferred pathways the roadmap satisfies the third criteria of a resilient strategy; its desirability by the organisation to implement. Including experts from the Port of Rotterdam together with the assessment of actions based on their contribution towards long-term-objectives excludes the need for establishing a monitoring system for contingency planning.

The final steps of the DAPP as designed by Kwakkel and Haasnoot therefore are not relevant in this research. Yet, a suggestion for further implementation is provided in the recommendations in chapter 9.

2.2. A CASE STUDY AT THE HARBOURMASTER'S DEPARTMENT

Since the DAPP framework has not been applied to guide decision-making for a specific organisation in the context of digitalisation and automation, it is tested by means of a case study at the Harbourmaster's department. This section elaborates on the case study method. A more extended overview of this method, and other methods used within the case study can be found in appendix B and in the corresponding sections.

The main objective of case studies is to expand theories (analytic generalisation) and not to enumerate frequencies (statistical generalisation). In this research, the DAPP-framework serves as a template with which to compare the empirical results of the case study where these results lead to a broader theory (Yin, 2014). The main objective of the case study is to test if the DAPP can be used to design a resilient strategy for the Harbourmaster to anticipate to changes in the port-call-process due to digitalisation and automation.

Traditional prejudices towards case study, lie in the validity and reliability of the method. This is avoided by using multiple sources of evidence and to have the results reviewed by experts (Yin, 2014). Figure 2.4, shows the design of the case study in this research.

The light grey box contains all methods that are used to obtain the information required in this case-study. Four methods have been applied: literature study, expert interviews, scenario analysis and a brainstorm-workshop. Both the literature study as well as expert interviews were used in the first phase of this research to gain more information about the port-call-process and digitalisation and automation. In total, eight expert interviews were held with experts within the Harbourmaster's division as well as external parties (see appendix C. In this research an expert is someone who has substantial knowledge of the field of research and works with the topic on daily basis, is not afraid to deal with the uncertainty and has the power of imagination (Enserink et al., 2010; Lipinsky & Loveridge, 1982; Porter et al., 1991). The interviews led to an in-depth analysis of the system and its requirements. The literature review together with expert interviews served as input for the scenario analysis.

The development of scenarios is done according to the steps of Schwartz and leads to a description of four scenarios of the port-call-process with respect to digitalisation and automation. To improve the validity and reliability of this case study research, a brainstorm workshop is organised to identify potential usable actions in multiple scenarios to prepare for threats and to seize opportunities.

By involving employees of the Harbourmaster's organisation in this workshop actions are developed that fit in the Harbourmaster's processes. These actions served as input for the final resilient strategy roadmap that can be used to identify a resilient strategy for the Harbourmaster to anticipate to uncertainties in the port-call-process in a changing environment due to digitalisation and automation. The final reflection reviews the applicability of the DAPP to design resilient strategies. Adjustments and improvements might contribute to an expansion of the DAPP-framework (Theoretical framework+).

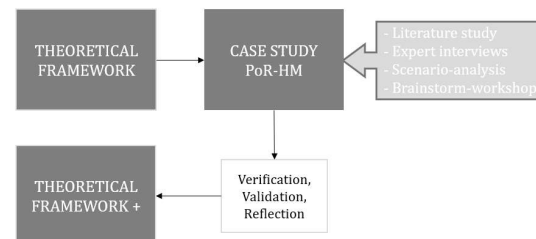


Figure 2.4: Case study research design used in this research

2.3. CHAPTER SYNTHESIS | THEORETICAL FRAMEWORK

In this research, a resilient strategy is defined as a strategy helping the organisation to survive, adapt and grow in face of changes in its environment, while guiding decision making towards long-term-goals. In addition, a strategy is perceived resilient if it is desirable by the organisation to implement.

The Dynamic Adaptive Policy Pathways framework developed is applied to design resilient strategies. This

seems a promising approach because this integrated approach includes scenarios representing a variety of relevant uncertainties and their developments over time; different types of actions to handle problems and opportunities of digitalisation and automation and adaption pathways describing sequence of promising actions. The final deliverable is a resilient strategy roadmap.

Adaptions are made to the DAPP for it to fit in this research. Firstly, the resilient strategy roadmap is designed for the Harbourmaster, therefore it is essential to include the Harbourmaster in the development of actions. Secondly, the DAPP in this research is a qualitative approach, meaning the sell-by-dates, sequence of actions and contributing of actions towards long-term-objectives have been assessed based on interviews and literature. Furthermore, to contribute to the resilience of a strategy the preferred scenario and actions is taken into account when designing the resilient strategy roadmap.

This research is a case study at the Harbourmaster's department and the use of the DAPP to design resilient strategies will be tested within this case study. The final conclusion will reflect on this method and might lead to an improved framework.

I

CONCEPTUALISATION

CURRENT PORT-CALL-PROCESS

This chapter is aimed at mapping the port-call-process and identifying the role of the Harbourmaster in this process. By doing so, it answers the first sub-question: 'How is the port-call-process currently organised?'. In this context, a process is 'the path of work that "crosses" several functions, plus the architecture that connects the relevant activities, people, information systems, and other resources along that path' (Damelio, 2011). The role of the Harbourmaster and other parties contributing to this process, the resources they use and issues they face is analysed by means of interviews, literature and participating in the daily tasks of the nautical services and Harbourmaster departments.

The port-call-process is a complex system consisting of many elements that are synchronised in order to manage the vessel traffic in the Port of Rotterdam. In the first section, the definition and scope of the port-call-process in this research is elaborated. Next, all relevant organisations in the port-call-process and their functions are discussed. Followed by section 3.1.2 in which all information infrastructure that is used to support the port-call-process is substantiated upon. The final deliverable of this chapter is a process-map summarising all aspects involved in the port-call-process.

3.1. THE PORT-CALL-PROCESS

The port-call-process, as is defined within this research is 'the processes and actions involved with the completion of vessel traffic between the first notion of an arriving vessel and the moment of the last contact'. In seaports, various services are provided that support a ship in the port-call-process. These services together form the nautical chain. 'Chain' in this context stands for a chain of events regarding servicing a vessel on her inbound, outbound or shifting voyage in which several organisations cooperate with a common goal, in this case, efficient completion of navigation in the Port of Rotterdam (Seignette, 2010). The vessel voyages in the nautical chain for the three types of vessel movements are defined in table 3.1.

Table 3.1: Nautical chain for inbound, outbound and shifting vessels

	Start	End
Inbound	First contact of vessel with the VTS requiring to enter the Port	Vessel is safely moored at the quay
Outbound	Vessel indicates she wants to leave her berth and the Port	Vessel leaves 'Pilot Maas' area
Shifting	Vessel indicates she wants to shift	Vessel is safely moored at next quay

Following sub-sections discuss all relevant organisations, processes and supporting information infrastructure for the three types of voyages in the port-call-process. For the sake of simplicity, all descriptions within this report are only focusing on inbound voyages. This is perceived to be sufficient since all three types of voyages are executed by the same organisations using similar sources of information (Seignette, 2019).

3.1.1. ORGANISATIONS IN THE PORT-CALL-PROCESS

To guide the inbound, outbound and shifting vessels in their journey, several parties are important in the chain. This broad overview of organisations, tasks and responsibilities is the result of multiple interviews with experts (Golden, 2018; Groot et al., 2019; Maan, 2018; Neef, 2018; Seignette, 2018; Tabak, 2019). Processes of these organisations are listed and elaborated below and further explained in Appendix C and D:

- **Harbourmaster.** The Harbourmaster is responsible for a safe and efficient completion of navigation. In order to contribute in an efficient vessel traffic management, four of the services of the Harbourmaster (see section 1.1) are important in the port-call-process.
 - **Vessel Traffic Service.** Vessel Traffic Service (VTS) is a service to promote traffic fluency and safety in ports (Praetorius et al., 2015). For this purpose, VTS provides information services, traffic organisation services and navigational assistance services (Chong, 2018). The VTS at the Harbourmaster's department monitors all vessels entering and leaving the Port of Rotterdam. It has contact with the vessel masters about routes and safety and deals with operational clearances (see section 3.2). The VTS checks whether or not the vessel has administrative clearance and if the data whereupon this clearance has been granted still is up to date. In case of constraints, the VTS operator instructs the vessel and discusses further course of action. An individual VTS workstation mainly is equipped with a VHF radio and a computer with the electronic chart with integrated radar and AIS. The VTS operator assesses the real-time traffic image based on data from VHF and AIS. Feedback from Aramis and HaMIS (see section 3.1.2) and other information systems (e.g. email, pilot schedule), keeping in mind the up-to-date hydro- and meteo circumstances (Costa et al., 2018). In addition, short-term planning will be monitored to make sure no congestion or any potential dangerous situations can happen. Furthermore, the VTS operator is responsible for traffic guidance from the Maas Approach area to the vessel berth (via VHF or in case physical guidance is needed via patrol vessels).
 - **Harbour Coordination Centre.** The Harbour Coordination Centre (HCC) is located in the World Port Centre and controls planning and access of vessels. It takes part in the administrative and operational clearance procedures. It checks the NOA and the legal report duty of the vessel and informs the vessel traffic operators, the patrol vessels, inspection and nautical services. In addition, the HCC checks the availability of the destination berth and if there is help required from the nautical service providers (NSP), the HCC will check if the deployment has been planned. Furthermore, the HCC monitors the vessel voyage and the port and in case of an incident, the HCC assesses the situation and its consequences for vessel traffic, send patrol vessels when needed and informs the NSP and other relevant parties. Unlike the VTS, the HCC has no direct contact with the vessel.
 - **Inspection.** Incoming and outbound vessels get checked whether or not they are compliant with the shipping regulations concerning environment and safety. During the administration of a port-call, apart from the HCC, the inspection is needed to check the safety- and milieu aspects as well as the nautical activities of the call. Physical inspections will be done in case the concerning nautical activities have been given a priority based on the administrative assessment (see section 3.2). Non-planned inspections occur in case the patrol vessels notice peculiarities concerning vessel behaviour, situation on board, port security and condition of infrastructure.
 - **Patrol vessels.** The patrol vessels (PVs) are responsible for inspection and enforcement on the water. If necessary, the patrol boats guide the vessels physically and assist vessels in the event of incidents. Physical guidance is needed in for instance when a vessel has to make special manoeuvres causing a blocked waterway, or in case of heavy deep vessels that only can enter the port in a certain time period. The VTS operator communicates with the PV operator after which a PV will go to the vessel at the designated time.
- **Nautical services.** The pilot, tugboat organisation and the boatmen together form the so-called nautical service providers (NSP) (Scherpenzeel & Römers, 2018). The NSP are requested by the shipping agent via Portbase in HaMIS and checked by the HCC on legislation and safety.
 - **Pilot.** The pilots guide vessels longer than 75 meters into and out of the Port in order to achieve a safe and smooth traffic in the port. They will (dis)embark the vessel via a helicopter or boat, depending on the weather and vessel-type and -size. The pilot boards a vessel before it enters

- the Pilot Maas area and will from that moment on guide the vessel to her berth in a safe and efficient way (Groot et al., 2019; Tabak, 2019). He or she will discuss the pilot passage plan with the vessel master, informs the VTS operator who subsequently update the ETA and determines whether or not and how many tugs and boatmen are needed. Pilots in this research are from the region Rotterdam-Rijnmond. Since not all pilots have the same qualifications and not all vessels have the same characteristics, it is important to check which pilot can serve which type of vessel to which area in the port or hinterland. During the voyage of the vessel the pilot keeps contact with the VTS operators. The vessel master in all circumstances is responsible for the vessel.
- **Tugboats.** Tugboats help to manoeuvre vessels in the port by either pushing or towing it since this often cannot be done safely by a vessel herself. The tugs accompany both inbound and outbound vessels from the entrance of the harbour to the quay. They meet the vessel near the entrance of the destined harbour and connect to the vessel in coordination with the pilot on the bridge. Without tug-assistance many vessels would have trouble manoeuvring in the harbours which would cause delays and possible dangerous situations.
 - **Boatmen.** The boatmen from the Koninklijke Roeiers Vereniging Eendracht help (un)mooring the vessels to and from the quay. They collect the ropes of the vessel, bring them to the quay, buoys or jetty where they attach them or hand them over to a colleague who attaches them to the bollards (Neef, 2018). This is done according to the mooring arrangement. Vessels larger than 75 meters are obliged to employ the services of the boatmen. All boatmen can serve all vessel types and it almost never occurs that no boatmen is available in time.
 - **Terminal operators.** A terminal is operated by a terminal operator. At the terminal the cargo is loaded on to or unloaded from the ship after which the loading will be transported to its final destination by truck, train or inland shipping. The terminal is responsible for providing its quay planning to the other organisations.
 - **Vessel.** The vessel entity consists of the vessel master, who is sailing the vessel and the shipping agent, who is the representative of the vessel on shore and assists in facilitating the port call.
 - **Master.** The Master of the vessel is in command of the vessel and represents the vessel owner and cargo interests and is responsible for providing all the information and the well-being of the vessel. It is obliged to notify the Harbour Master before arriving or leaving the Port (Ministerie van Infrastructuur en Milieu, 2016). The master of the vessel sends the time of departure from the port of origin when he departs via a land-side network. Since contact is difficult and expensive, the vessel master almost has minimal contact with his agent on the land-side. Via email, updates of the travel voyage, depth and cargo will be exchanged between the vessel master and agent.
 - **Shipping agent.** A shipping agent is the representative of a vessel in the Port. The agent makes sure that important services to (un)berth the ship, such as pilots, tugs, bunkering and waste disposal, are ordered. The agent provides all necessary information (ETA, ETD, need of nautical services) relating to the voyage to the relevant parties, such as the Harbourmaster (Ministerie van Infrastructuur en Milieu, 2016).

Each of these organisations, contributes to an efficient port-call-process by working closely together. The Harbourmaster has the duty to manage vessel traffic by gathering all information and services provided by the organisations and communicate all relevant information with the vessel master and the NSP to maintain a smooth completion of vessel traffic. Vessel Traffic Management in this report is defined as the management of all services and reliable information needed by the interacting organisations in the port-call-process. The objectives of this duty are elaborated in chapter 4. Essential for executing this task, is supporting (IT-)infrastructure providing the Harbourmaster of information.

3.1.2. INFORMATION INFRASTRUCTURE

Various information systems are used by the Harbourmaster and all other organisations in the port-call-process to provide information to support the completion of vessel traffic. Systems supporting the sharing and gathering of information in the port-call-process are Very High Frequency (VHF), Automatic Identification System (AIS), the Harbour Master Management Information System (HaMIS), Aramis and the Port Community System (PCS).

- **Very High Frequency (VHF).** VHF radio is considered an essential analogue tool and the primary means for interacting with vessels (Mansson et al., 2016). Any vessels in the nautical control area of the port of Rotterdam must listen to the correct VHF sector channel. Vessels can use the VHF channels to communicate by VHF radio with the two traffic centres in the PoR (Röhner, 2017). VTS operations depend among others on VHF radio voice communications. Protocol reporting communications, influence essential judgements and safety judgements all are exchanged via VHF. VHF is available 40 to 50 miles outside of the port area (Costa et al., 2018). VHF transmissions are openly broadcast, and therefore also used for overhearing communication which does not directly involve VTS but helps in interpreting the current state of vessel traffic. This is mainly important for accessing information regarding vessels that are not equipped with AIS or not transmitting AIS data. Problems with contacting vessels by VHF radio mainly lie within the technical field of VHF (poor sound quality and disruptions), but also language barriers, different interpretations or pilots and masters using the wrong VHF channel are problems with this communication method. To deal with these shortcomings, landline, satellite or mobile phones offer a solution for VTS operators, although this does not lead to the broadcast of information which makes it not accessible to all participants (Mansson et al., 2016).
- **Automatic Information System (AIS).** AIS is a digital automatic tracking system used on ships and by VTS for identifying and locating vessels by electronically exchanging data with other nearby vessels, AIS base stations and satellites. AIS is among others intended to allow port authorities to track and monitor vessel movements. It integrates a standardised VHF transceiver with a positioning system such as a GPS receive, with other electronic navigation sensors (Haunsoe et al., 2012). AIS data often if combined with radar data to increase the accuracy.
- **HaMIS.** HaMIS is the information system used by the HCC and VTS and the nautical service providers. The supporting data around it provides details on the voyage, the cargo, intended inspections and reference data for each vessel (Seignette, 2010). Operators can see for instance the actual traffic image, incidents, information on the vessels and occupied berths. The HCC uses the system to check whether or not administrative and operational clearances can be provided and the VTS operators use it to supplement the traffic image with specific port call data and monitor the vessel voyage. The PCS delivers relevant data to HaMIS.
- **Aramis.** The Advanced Radar Monitor and Information System, provides radar information retrieved from radar stations to the VTS-operator. It shows real time movements of vessels based on radar and AIS data. The system combines the radar images from the various radar posts in the port with AIS-data, which leads to an electronic nautical map of the waterways. By doing so a real time traffic image of the port is created which in combination with data from HaMIS, VHF and camera images is enough for the VTS operators to facilitate a safe traffic flow.
- **Port Community System (PCS).** The PCS in the Port of Rotterdam is used to share information regarding vessel voyages and cargo between various other information systems and actors. It is owned by Portbase and has coverage in almost the whole of the Netherlands (Portbase, 2018). Everyone in the logistics chain can exchange information via PCS easily and efficiently. According to the International Port Community System Association, a Port Community System is a trusted third part; a neutral and open electronic platform enabling intelligent and secure exchange of information between public and private stakeholders in order to improve the competitive position of the seaports community. It helps to optimise, manage and automate ports and logistics efficient processes through a single submission of data and connecting transport and logistic chains (Wiel, 2018). Without a PCS, all parties have to send information separately to all other parties in need of this information. With a PCS the information can be uploaded in one platform that distributes it to the relevant parties

3.2. PROCESS MAP

Literature has proven that an IDEF0 modelling diagram is an useful tool for mapping complex processes (Kim & Jang, 2002; Lightsey, 2001; Razali et al., 2010). It is designed to model the decisions, actions and activities of a system in a graphical form and helps in establishing the scope of analysis. An IDEF0 model consists of various subsequent activities. Each activity, converts input into output, while receiving support from the enablers. Control variables can be used to steer the activity. A classic syntax of an IDEF0 model is presented on the left side in figure 3.1. Inputs are shown as arrows entering on the left side of the activity box, while outputs are exiting on the right side of the box. Controls are displayed as arrows entering on top of the activity box and enablers enter the activity box on the bottom.

In the processmap of the port-call-process, the enablers are the organisations in the port-call-process and visualised in a light grey box on the bottom of the activity. The controls are the information that is needed to execute each of the activities. It is divided in the supporting information system (white box on top of the activity) and the information (entering arrow on top of the activity). Furthermore, the clearances that are provided or not are represented with a diamond-shaped box.

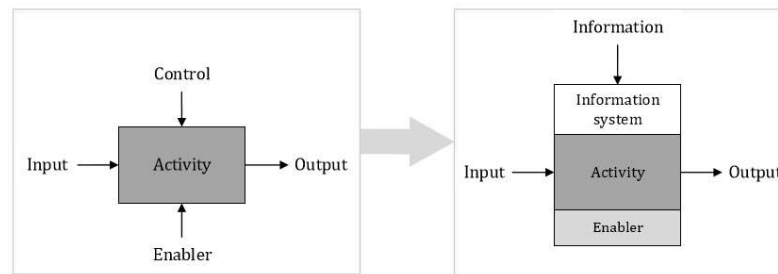


Figure 3.1: IDEF0 diagram application for the port-call-process

The IDEF0 approach to model the port-call-process together with the information of the processes of all organisations and the information they use leads to figure 3.2. Six sub-processes are identified that will be elaborated next.

- I The agent is the only one who has contact with the vessel. By email the vessel master notifies the agent with its more accurate estimated time of arrival in the Port. All contact with the vessel, until the Pilot Maas area, will be done via the agent.
- II 24 Hours before the vessel arrives in the port, the agent is obligated by law to give the Notice of Arrival (for outgoing voyages this is called Notice of Departure) in the PCS. This notification is made in Portbase (PCS) and contains information on the ETA of the vessel, the position, the name and identification number of the vessel, the draught, waste, security, shipping activities, the total amount of people on board, special circumstances (permits e.g.) and the ordering of the nautical service providers (Röhner, 2017). Via Portbase the information will serve as input in HaMIS.
- III Two hours before the estimated berthing time, the HCC together with the Inspection (security, waste & dangerous goods) will check the NOA based on the data in HaMIS. When the notice is not sufficient, the HCC will give feedback to the agent who now has to make sure the information missing will be provided to Portbase. In addition, the HCC checks whether or not the ordered berthing place is available on the estimated time of arrival. This clearance also contains a check for the order of nautical services. The ordered amount of NSP can be adjusted by the working operator if he thinks this is necessary based on his experience, weather-circumstances or the type of berth. Information will be provided in HaMIS and accessible to the NSP. This check takes 5 minutes in total (Maan, 2018). In case the NOA is correct, and there are no more actions needed to be taken by the agent, the HCC and Inspection will provide administrative clearance to the vessel. The vessel is now allowed to enter the Maas Approach area. In the occurrence of an incorrect NOA, this will be reported back to the agent who on his turn has to complete or adjust the NOA. When a physical inspection is needed the Inspection does this after which the NOA might be approved.
- IV The HCC together with the VTS provide the operational clearance. This clearance involves a check of the data upon which the administrative clearance has been given is still up to date. As soon as the

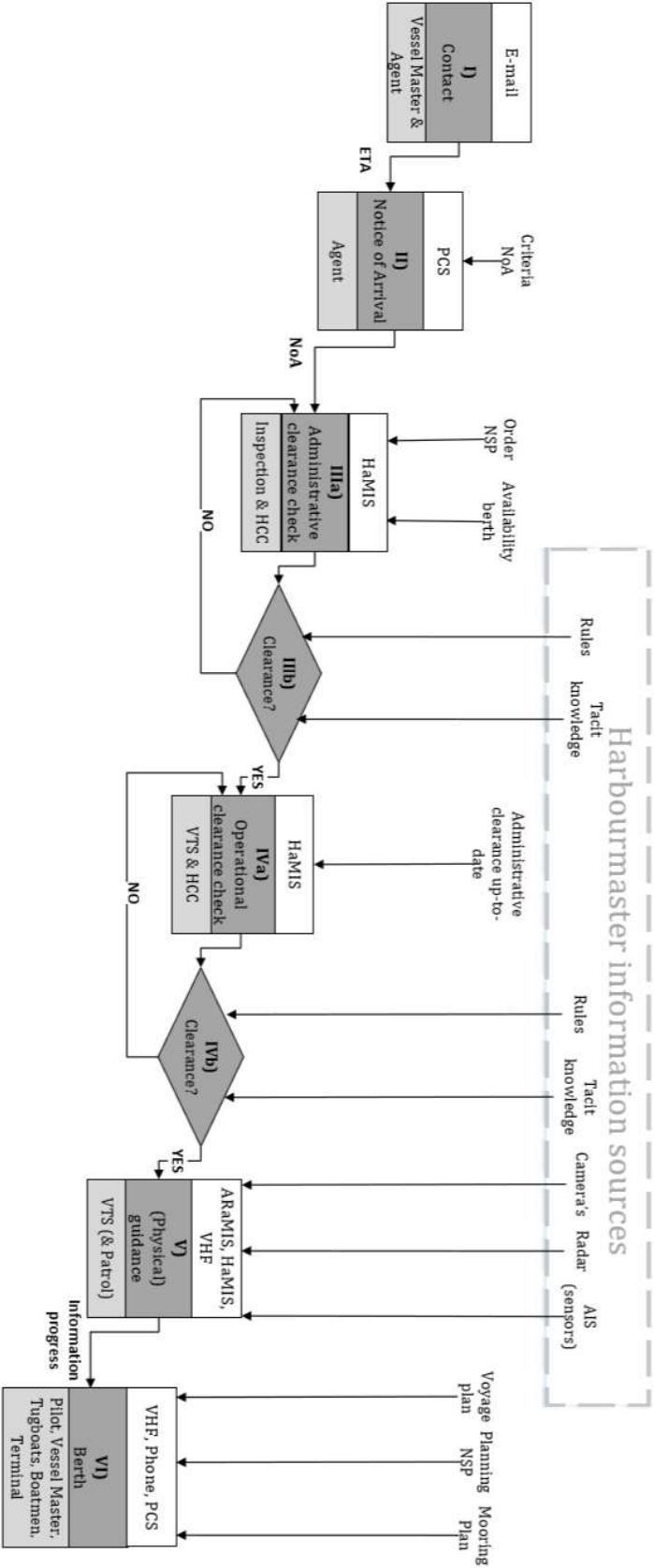


Figure 3.2: Process map of the current port-call-process

operational clearance is provided, the vessel can sail into the Pilot Maas area. This is the first contact with the VTS and from now on the VTS tracks the vessel based on information provided by AIS, wind sensors, cameras and radar data which is visible via Aramis and HaMIS.

- V The HCC checks, based on the amount of traffic in the port, advice from the inspection (concerning environment and safety) or in case of special transports and vessels confined due to their draught whether or not physical guidance is needed. When this is the case, a patrol vessel will guide the vessel to its berthing place.
- VI In case a pilot is required, he or she will embark the vessel via a fender or by helicopter on the specific pilot embark locations. Earlier, both the pilot and captain made their own voyage planning based on their knowledge of the port waterways and the vessel characteristics and capabilities. After embarkment of the pilot, they exchange their plans after which they together adjust the plan of voyage. In case the pilot needs to change his plan (for instance due to failures on the vessel), the pilot-master plan, will be laid next to the VTS voyage plan and adjusted. Subsequently, the VTS operators will insert this in HaMIS.

In case tugs were ordered, they meet the vessel at the tug-meeting point where they from then on help the vessel to manoeuvre in its harbour.

When the vessel is near its berthing location, the boatmen from the KRVE together with the crew and instructed by the vessel master and pilot, help to moor the vessel. The boatmen, tugs and pilot cooperate together in order to make sure the vessel will be moored safely and efficient. When the vessel is moored, the NSP will go on to their next assignment. The agent and vessel master are responsible for the vessel when it is berthed. The patrol vessels monitor the shipping activities when the vessel is moored.

3.3. CHAPTER SYNTHESIS | CURRENT PORT-CALL-PROCESS

This chapter, serving as the first step of the DAPP-framework, is aimed at giving an overview of the current port-call-process. By doing so, it provides an answer to the first sub-question *'How is the port-call-process currently organised?'.* By means of expert interviews and a literature study the port-call-process and the organisations are conceptualised.

The port-call-process is divided in six sub-processes. These are organised by adequate information exchange and a strong collaboration between the Harbourmaster, the Nautical Service Providers, the terminal, the vessel master and the shipping agent. Data from GPS, AIS, cameras and nautical rules is processed via IT-software. In addition, tacit knowledge appeared to be an important source as well to make decisions in the port-call-process.

The role of the Harbourmaster, subdivided in the Harbour Control Centre, Vessel Traffic Service, Patrol Vessels and Inspection, lies in managing the vessel traffic in all six processes by gathering all information and services provided by the organisations and reporting the relevant information with the vessel master and NSP. By inspections and security checks, safety is maintained and by distributing information between all stakeholders the Harbourmaster facilitates an efficient completion of vessel traffic in the Port of Rotterdam.

4

OBJECTIVES OF THE PORT-CALL-PROCESS

Resilient strategies guide the organisation's decision-making towards long-term-goals. For this reason, it is essential to identify the objectives and vision of the Harbourmaster's division. By doing so, in this chapter an answer is provided to the sub-question 'What are the objectives of the Harbourmaster for the port-call-process?'. As has been described in chapter 3, in the port-call-process various organisations with their own procedures and interests are involved. The Harbourmaster is both part of this process and is responsible for facilitating the process as well. He is obliged to give account to the government about the performance of the process. This complex construction needs further clarification in order to understand the objectives of the port-call-process and whether or not these are the same as the objectives of the Harbourmaster's organisation.

First the need for performance measurement and setting objectives for the port-call-process is discussed as this is relevant in the design of a resilient strategy. In section 4.2 the complex environment in which the Harbourmaster operates is explained which helps in understanding the difference between the vision of the Harbourmaster towards the port-call-process and the performance indicators of the port-call-process, that are elaborated in section 4.3.

4.1. RELEVANCE OF PERFORMANCE INDICATORS

In order to design a resilient strategy, decisions about actions should be based on their contribution towards long-term-goals of the Harbourmaster in the port-call-process. Performance measurement is a fundamental principle of management and an aid to make decisions and guide the organisation's efforts to success (Locke & Latham, 2002; Riratanaphong et al., 2012; Shahin & Mahbod, 2007). It is important because it can identify gaps between the current and the desired performance of a system.

Since goal setting is typically formulated at a strategic level, key performance indicators reflect and derive from organisational goals and help to measure the performance by indicating the progress towards and achievement of these certain goals (Sage & Armstrong Jr., 2000). In this research understanding of performance measurement and the role of the Harbourmaster in the port-call-process is essential to be able to design a resilient strategy in a changing environment. In their book *The Success Principles*, Canfield and Switzer (2004) state that "Vague goals produce vague results" (Canfield & Switzer, 2004). To prevent results from being vague and to be able to use them in the design of a resilient strategy, each of the performance indicators, should be specific, measurable and attainable (Drucker, 1954; Macleod, 2013). However, the Harbourmaster is a State division, responsible for, and operating in a process in which more organisations are involved. This makes it harder to define the current vision and objectives. Therefore first a clarification of the environment of the Harbourmaster is needed.

4.2. THE ENVIRONMENT OF THE HARBOURMASTER'S ORGANISATION

Every organisation has its own context in which it operates. The Harbourmaster's operations, are affected and determined by many factors in his environment. On the same time, the organisation is able to influence its own context. This interaction in the context of the Harbourmaster has been described by Raymond Seignette in his context-diagram. The diagram shows how each layer operates at its own pace, protected from above by slower, larger layers and invigorated from below by faster, smaller cycles. By doing so, this diagram has

overlap with the four-layer model designed by Williamson in 1998, which focuses on describing social and institutional arrangement in complex systems (Ghorbani & Nikolic, 2010; Williamson, 1989). Because of the similarities between the two models, the context diagram by Seignette has sufficient scientific basis to be used within this research to illustrate the environment of the Harbourmaster. Figure 4.1 illustrates the application of the framework of Seignette in this research.

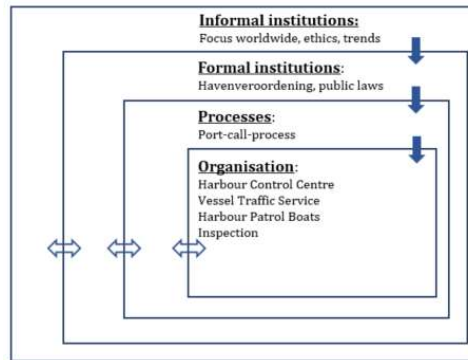


Figure 4.1: The environment of the Harbourmaster, based on Seignette's context diagram (Seignette, 2018)

The outer two layers describe the institutions that slowly influence the organisation top-down. Institutions are structures that lay restrictions on economic, social and political behaviour. Institutions are not set, but can be influenced and adjusted by the society in which they play part (Hazeu, 2007). In 1990, Noble price winner Douglas North made the distinction between formal institutions and informal institutions. Where formal institutions are decision-making-rules, the constitution, laws and contracts, informal institutions are behavioural rules, social norms and cultures. The formal institutions, define the condition under which processes in the organisation take or may take place. The Harbourmaster himself has his own procedures and culture, contributing to the processes (Seignette, 2018).

In this research, the informal institutions are the society and environment of the Harbourmaster. Since the Port of Rotterdam is affected by major trends in the world, the formal institutions correspond to these trends and the worldwide focus. This focus, the informal institutions, gives direction to the laws and rules. The formal institutions relevant for the Harbourmaster are the Havenveroordeening as well as public laws set by the government of the Netherlands and the municipality of Rotterdam, the EU rules and regulations and the global laws set by the International Maritime Organisation (IMO). In addition, the Harbourmaster is obliged to report his performance to the government. The laws determine the public mandate (e.g. the boundaries) of the processes of the Harbourmaster. However, he can choose his own position within these boundaries. The port-call-process is a public-law task, and the Harbourmaster can set specific conditions under which the port-call may take place.

The way the Harbourmaster performs this task is relevant not only to the Port itself but by maintaining a safe and efficient port-call-process this task can contribute to the international competitive position of the Netherlands as well. The port-call-process defines the required input from the organisation of the Harbourmaster. The Harbourmaster may and can extend his role in this process based on his preference. At this moment, this role contains the tasks elaborated upon in chapter 3; Harbour Coordination, Vessel Traffic Service, Patrol and Inspection. However, due to a long and complex history of this organisation, where the role of the Harbourmaster and his share and contribution to the port-call-process have changed over the years, the boundaries in which the Harbourmaster can operate can be interpreted in different manners and exact specifications are not defined. His role in the process, the organisation of Vessel Traffic Management and the level of governance required are not fixed and can change. This is an uncertain element in the organisation of the Harbourmaster and in the organisation of the port-call-process and should be taken into account in this research.

As has become clear, the main objectives of the port-call-process, do not have to be in line with the vision, goals and criteria of the processes of the Harbourmaster. Even though the port-call-process is a process re-

quiring information and activities from more organisations, the Harbourmaster is responsible for facilitating the port-call-process (see chapter 3).

4.3. CURRENT VISION AND KPIS

In this section both the objectives of the port-call-process, as well as the vision of the Harbourmaster towards the port-call-process are elaborated. The KPIS derive from the objectives of the port-call-process and are measurable indicators. The vision is what the Harbourmaster stands for, it is a strategic view of how he sees himself in the future. In section 4.3.1 the vision of the Harbourmaster is presented after which the KPIS that are used to assess the port-call-process are discussed in section 4.3.2.

4.3.1. VISION

The vision represents the strategic view of Harbourmaster about his future role in vessel traffic management, and thus his future contribution to the port-call-process. According to Jan Willem Verkiel, manager of the policy department at the Harbourmaster's division, the vision of the Harbourmaster is as follows (Verkiel, 2019; Verkiel & Molenaar, 2018):

*The Port of Rotterdam is the **smartest** port. The users of the Port experience a Harbourmaster's organisation that is involved with their interests, with a constant eye on **safety**. Processes are aimed to be as **efficient** as possible strengthened with smart information. In a rapidly changing environment the Harbourmaster's organisation is **adaptive** and **innovative**.*

The bold marked terms are the main objectives of the Harbourmaster. By being innovative, adaptive and by making use of the opportunities of digitalisation and automation, the Harbourmaster wants to improve safety and efficiency in the port-call-process. Safety and efficiency are the core values. Several programmes and projects to contribute to this vision are initiated and further elaborated in chapter 5, section 5.4. When designing strategies, important is to take into account strategies focusing on increasing safety as well as smart and innovative strategies that both fit in the current vision of the Harbourmaster. Strategies that fit in the current operations are more likely to be implemented than strategies that are new and might be disruptive (Al-Ghamdi, 1998; Heide et al., 2002).

4.3.2. KPIS

Derived from the aims of facilitating a safe and efficient port-call-process, several Key Performance Indicators are established. the Harbourmaster is required to report these KPIS to the State every quarter-of-a-year. The indicators relevant for measuring the performance of the port-call-process are (De Havenmeester, 2018; Verkiel, 2019; Verkiel & Molenaar, 2018):

- **Nautical Safety Index (NSI).** *Expresses the proportion of actual, nautical safety with respect to the nautical safety in the reference period. It is measured per year by counting and ranking the number of nautical accidents. Severe incidents have a higher weight. The score is compared to the reference period 2012-2015, that has a norm of a seven out of ten. The target score of this KPI is an eight out of ten.*
- **Safety & Environmental Index (SEI).** *Expresses the proportion of the current safety with respect to the safety in the reference period. Safety in this context is about transportation- and environmental safety. It is measured by inspecting vessels. In the occurrence of a delict, it is registered. The more severe the delict the higher the weight in the final score. The score is compared tot the reference period 2014 which is standardised at score 7,5.*
- **Nautical Efficiency Index (NEI).** *Is in development and expresses the proportion of the actual total amount of time of the vessel voyage with respect to the norm of that voyage.*

Furthermore, Water pollution, the amount of claims and port security with respect to terrorism are criteria for the Harbourmaster too (De Havenmeester, 2018). Since these do not influence the port-call-process they have not been taken into account in this research.

The KPIS as reported are not formulated precisely and can be interpreted in different ways. Both safety indicators are formulated and measured in a general manner. For instance, the definition of safety can differ per situation and depends on the person evaluating it. It was generally described as the avoidance of accidents or taking the right measures to 'minimise' impact in case of an incident or accident. However, in reality, the

concept of safety seemed to be more individual and subjective (Praetorius & Lützhöft, 2011). It is also based on operator knowledge and experience. Somebody who is working at the HCC for 20 years may think a certain situation is not safe, or extra assistance might be needed, even though according to the rules and theory, the situation is safe and the vessel can sail safely without assistance. The operator may know the vessel type, knows how it can react to the weather circumstances, knows the pilot and knows the difficulty in manoeuvrability of the vessel in this particular harbour. This tacit knowledge applied due to a lack of standardisation is hard to describe in words and leads to a challenge when defining a safety KPI.

The difficulty in measuring safety and efficiency is strengthened by the fact that there is a distinction between the responsibility of the Harbourmaster and the responsibility of all other organisations in the port-call-process. This is the result of the port-call-process being an overarching process, in which many other factors and organisations are involved, all having their own interests and institutions as described in section 4.1.

4.4. CHAPTER SYNTHESIS | OBJECTIVES OF THE PORT-CALL-PROCESS

Performance measurement is a helpful tool to guide the Harbourmaster in decision-making to reach long-term goals and objectives. To design a resilient strategy in a changing environment due to digitalisation and automation, its relevance therefore lies in verifying whether or not the organisation still is on the right path to achieve these goals. In addition, being aware on how to reach objectives can help to identify threats and opportunities affecting the performance of the Harbourmaster. In this chapter an answer is provided for the third sub-question *‘What are the objectives of the Harbourmaster for the port-call-process?’*.

The complexity of this question lies in the fact that the objectives of the port-call-process and how they are currently measured, do not have to be in line with the vision of the Harbourmaster towards the port-call-process. For an organisation such as the Harbourmaster, performance measurement is not just relevant for the organisation itself, but is important for the environment as well. Informal and formal institutions determine the boundaries of the port-call-process and the extend to which the Harbourmaster can contribute to the objectives of the port-call-process. Depending on the way the Harbourmaster positions himself in the processes that are part of his environment, his contribution to the performance indicators can change.

The objectives that are used in this research to assess the actions for the resilient strategy roadmap are a combination between the KPIs of the port-call-process and the vision of the Harbourmaster: safety, in terms of number of accidents, and efficiency, in terms of vessel delays. A vessel is delayed if the total time of the first contact between the vessel and its berth is bigger than the norm. The safety-environmental index will not be taken into account in further research because it fits less with the vision of the Harbourmaster. Also, the power of the Harbourmaster for the environmental safety only lies in mitigating the impact of accidents and not in avoiding them in general. Safety and efficiency serve as a qualitative indicator in the third step of the adjusted DAPP-framework where the designed actions are verified whether they guide towards the long-term-objectives.

As a final note, the KPIs and vision of the Harbourmaster as specified at this moment are difficult to measure and need a better specification. In addition, to identify the impact of digitalisation and automation as well as actions to respond to this trend, recommended is to specify operational KPIs to measure the performance of all sub-processes identified in chapter 3, section 3.2. Examples of these indicators can be ‘number of times a NOA was not correct’, ‘duration of the clearance checks’ or ‘number of miscommunications in information exchange in (physical) guidance’.

5

TREND OF DIGITALISATION AND AUTOMATION

An uncertain future is ahead due to a number of trends in the environment of the Harbourmaster's organisation. The focus in this research is on one of the major trends, digitalisation and automation. This trend might change the port-call-process and the role of the Harbourmaster. This chapter lays hands on the second sub-question 'How might the trends of digitalisation and automation affect the current the port-call-process?'.

To answer this question, first the position of the trend in the environment of the Harbourmaster is discussed. Followed by section 5.2, where the terms digitalisation and automation are described as well as the interpretation of these definitions in this research. This leads to a clear structure that can be used when analysing the impact on digitalisation and automation in the port-call-process. Next, the areas affected by digitalisation and automation are identified based on the process map presented in chapter 3. In section 5.4, the current initiatives in the Harbourmaster's organisation to anticipate to this trend is elaborated upon

5.1. RECAP OF THE ENVIRONMENT OF THE HARBOURMASTER

Digitalisation and automation, is a global trend becoming wide-spread in society, rules, processes and organisations. Since it is a trend that covers all four layers (see figure 5.1), the trend might have major consequences in the port-call-process and for the role of the Harbourmaster. Where the informal institutions decide whether or not the trend is ethical, and conform the norms of the society, the formal institutions decide whether or not the application of the trend is allowed. Without rules that support digitalisation and automation, it is difficult for a trend to be applied in the organisational processes of the Harbourmaster. For the port-call-process, digitalisation and automation offers solutions to problems but creates problems as well. The organisational structure, responsibilities and role of the Harbourmaster might change due to the impact of this trend.

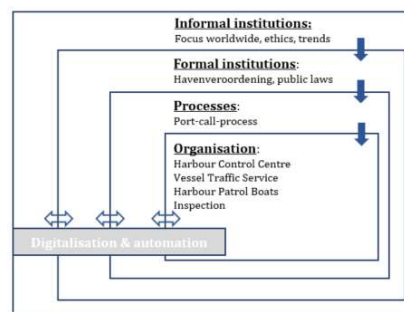


Figure 5.1: Digitalisation and automation in the environment of the Harbourmaster

5.2. EXPLANATION OF THE TERMS

In literature, different definitions are employed when one describes digitalisation and automation. Scientist, governmental- and business organisations interpret the terms in a different manner, and so will Harbourmasters. How digitalisation and automation should be interpreted when studying its impact on the port-call-process, will be discussed in this section.

5.2.1. DIGITALISATION

Originally, digitalisation describes the conversion of analogue to digital information and processes (Negroponte et al., 1997). However, many institutions have given their own turn to this definition. Scientific articles often employ a similar definition. As described by the Oxford English diary, digitalisation is 'the conversion of information into a digital form, so that they can be processed by a computer'. According to Eurofound (2018) in a report about implications of digitalisation and automation, digitalisation is 'the use of sensors and rendering devices to translate (parts of) the physical process into digital information (Fernández-Macías, 2018). Another representation of digitalisation is 'the integration of multiple technologies into all aspects of daily life that can be digitised' (Gray & Rumpe, 2015). A clear overlap this definitions have, lies in the fact that they all name the conversion of information in their description of digitalisation, via various forms of technology. Gartner and McKinsey, two of the worlds leading consulting and business organisations, does not bother about the converting information when they describe digitalisation. They define it as 'the use of digital technologies to change a business model and provide new revenue and value-producing opportunities'.

What is clear, is that the definitions of digitalisation and automation differ per organisation based on the organisation's means and interests. In profit and business oriented organisations, digitalisation is aimed at changing business and make use of opportunities while scientific articles have a more objective focus. The Harbourmasters division, not aimed at doing business but on providing service, will employ a traditional use of the term digitalisation where not only opportunities for its operations have to be analysed but threats as well. In this research digitalisation is defined as '*the transition of data and processes from analogue to digital*'. There is a difference to be made between 'digitalisation of data' and 'digitalisation of processes'. In this research, data serves as input for the system and the way data is transformed is the output of the system. Figure 5.2 illustrates this.



Figure 5.2: Digitalisation in the port-call-process

5.2.2. AUTOMATION

Definitions of automation in literature are quite a like. The Oxford English Dictionary (2006) defines automation as 'the application of automatic control to any branch of industry or science; by extension, the use of electronic or mechanical devices to replace human labour'. A more operational definition of automation is that it contains the use of computers to interpret and record data, make decisions, and visualise information (Lindström et al., 2008). The main difference between the definitions is the role of the human operator. In an automated system, Muiri et al (1994) states this role is to supervise the automation and intervene to take manual control when necessary. According to Thurman et al. (1999), human tacit operational knowledge and problem solving skills needs to be encoded in order for a system to perform operational activities in a manner similar to operational personnel. Kling et al. (1982) describe this role of automation to be more supporting: 'in an office environment, automation is generally considered as the use of integrated computer and communications systems to support administrative procedures' (Kling Editor et al., 1982). Besides the human factor, the level of automation differs as well in the definitions. Parasuraman et al. (2000) state that automation does not simply refer to technical innovation or modernisation. It is a system that accomplishes (partially or fully) a function that was previously, or conceivably could be, carried out (partially or fully) by a human operator. This implies it can vary across a continuum of levels of fully manual to full automation (Parasuraman et al., 2000). Derived from the definitions is that before a system can be automated, first data needs to be obtained by recording and interpreting data. The translation of this data from analogue to digital (digitalisation) is a start when creating automation in a system. Automation in this research is defined as '*By means of digitalisation, acquire data and human tacit knowledge so that the system can replace (partially to fully) human labour*'.

This definition implies that there are multiple levels of automation, from partially to fully automated. Four levels of automation can be distinguished. Depending on the level of automation, it can be applied in the input, output and in the system itself (Parasuraman et al., 2000). The system is the port-call-process, a sub-process or a part of a sub-process (actions, agreements, checks, transport, etc.). The levels of automation can be explained as follows:

- **Information acquisition.** This first level of automation, refers to the acquisition and registration of multiple sources of information. It includes positioning and orienting of sensory receptors, sensory processing and pre-processing of the data so that it can be used. In addition, the incoming data needs to be filtered since not all data is relevant for all purposes and parties.
- **Information analysis.** In this level, massive volumes of data have been collected from different sources and by different stakeholders. Combined with the capabilities to program algorithms that add to the intelligence of the digital information and the operating logic, the system can be automated (Leviäkangas, 2016). This requires business rules, big data analysis and machine learning (NISS, 2016). Via the information analysis (parts of) tacit knowledge can be converted into business rules. Over time, it can also help in augmenting human operator perception and cognition (Loebbecke & Picot, 2015).
- **Decision selection.** In this stage decisions are reached based on cognitive processing in the second level. Specific decision choices can be prescribed if particular conditions exist. With the analysis of information, in this level the system makes assumptions about the different outcomes of the possible decisions. In this level, automation is a decision support tool, the final decision to accept or ignore the suggestion is for the human operator.
- **Action implementation.** This level involves the implementation of an action consistent with the decision selection. It involves different manners of machine execution of the choice of action and typically replaces human actions.

5.2.3. INTERACTION OF DIGITALISATION AND AUTOMATION

The extent to which the definitions in reality are overlapping, or influencing each other is conceptualised in figure 5.3.

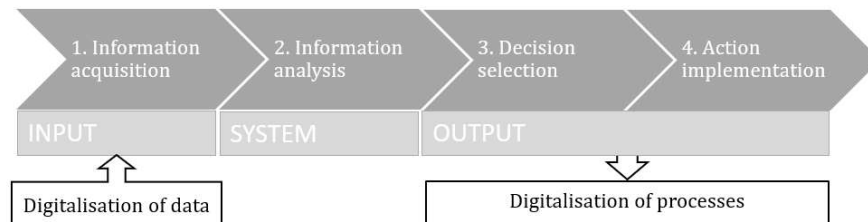


Figure 5.3: Interaction of automation and digitalisation

Without digitalisation of input data, processes cannot be automated. Furthermore, when a system output is automated, one can speak of digitalisation of the processes. In the port-call-process, data and processes that now are analogue, are eligible for digitalisation. In technical sense, analogue information can be distinguished from digital information in the sense that in analogue technology, information is translated into electric pulses of varying amplitude. In digital technology, information is translated into a binary format (either zero or one). For the Harbourmaster processes, it comes down to the distinction that digital information is best suited for computing and digital electronics (software programmes), while analogue information is acquired by a human operator.

The level of automation can vary and be combined across all levels. For instance, the assignment of NSP is automated till the third level. This means that a decision is made automatically about the amount of NSP required for a certain vessel voyage. In case the HCC operator does not notice this suggestion of the system, or in case he is occupied, the selected decision will be implemented after five minutes (level four). When the

HCC operator does notice the suggestion and does not agree with it, he can adjust the decision analogue, by sending a digital notice to the NSP.

This is only an illustration of one part of a sub-process of the port-call-process. Digitalisation and automation can affect the six sub-processes of the port-call-process in various ways.

5.3. AREAS OF IMPACT IN THE PORT-CALL-PROCESS

The impact of digitalisation and automation in the port-call-process is assessed qualitatively. Information has been retrieved via interviews and literature studies (see appendix C).

5.3.1. POTENTIAL OF AUTOMATION AND DIGITALISATION IN THE SUB-PROCESSES

The impact of digitalisation and automation in the port-call-process, depends on the level of automation and on the area of digitalisation. The process-map presented in chapter 3 serves as a guideline to analyse the potential areas of impact of digitalisation and automation. As is discussed in section 5.2.3, the impact can be found by identifying the areas with analogue information exchange and by elaborating on the potential for automation. Figure 5.4 shows all parts of the port-call-process that are currently analogue (red) and digital (green).

I Contact between agent and vessel

How? Analogue via email and phone contact.

Potential for digitalisation: The most important information that is exchanged is the more accurate ETA. This data can be digitalised with more accurate and advanced GPS sensors providing the right AIS information.

Potential for automation: On all four levels automation has its potential. The GPS data can be generated and transmitted automatically to the Port Community System. This information combined with predictions for vessel courses, fluent, wind and traffic intensity, can lead to an accurate prediction over time. This predicted ETA can either serve as a suggestion for the agent who can accept or adjust it (Level 3), or it can even be sent to the PCS automatically (Level 4) (Tabak, 2019).

II Notice of Arrival

How? The information provided in the NOA, is requested by the agent and typed in into a computer analogue, and sent digitally to Portbase.

Potential for digitalisation: Information provided in the NOA is static information except for its position, can partly be digitalised. This means, the information has to be provided by shipping companies and sent digitally to Portbase.

Potential for automation? Information in the NOA is delivered by different sources (sensors, shipping companies, regulations). When vessel characteristics (length, depth, load, etc.) are automatically provided in the system, it is possible to define the amount of NSP needed, draught of the vessel, shipping activities. If this is the case, the information can be automatically sent to the port-community-system.

III Administrative clearance

How? The administrative clearances are provided analogue by the HCC and Inspection to the agent and vessel master.

Potential for digitalisation: The HCC and Inspection do the check based on both regulations and tacit knowledge. Where it is easily possible to digitalise regulations, tacit knowledge is a decision-making tool and is therefore discussed in the potential for automation.

Potential for automation: Following up on the NOA in the second process. In case all information is provided digitally, it is possible for the system to analyse the information automatically (Level 2), make a suggestion for the outcome of the administrative clearance check (Level 3) that can be accepted or ignored by the operators at the HCC and Inspection. It could even be possible for the system to decide and act upon it by giving feedback to the agent automatically (Level 4). In the furthest extension of automation in this process, the administrative clearance is provided to the vessel automatically, after which the vessel knows it is now allowed to sail into the Maas Approach area and automatically continues its voyage. Physical inspections cannot be automated to the furthest extend but by means of drones the data can be digitalised, and via big data analysis decisions can be suggested.

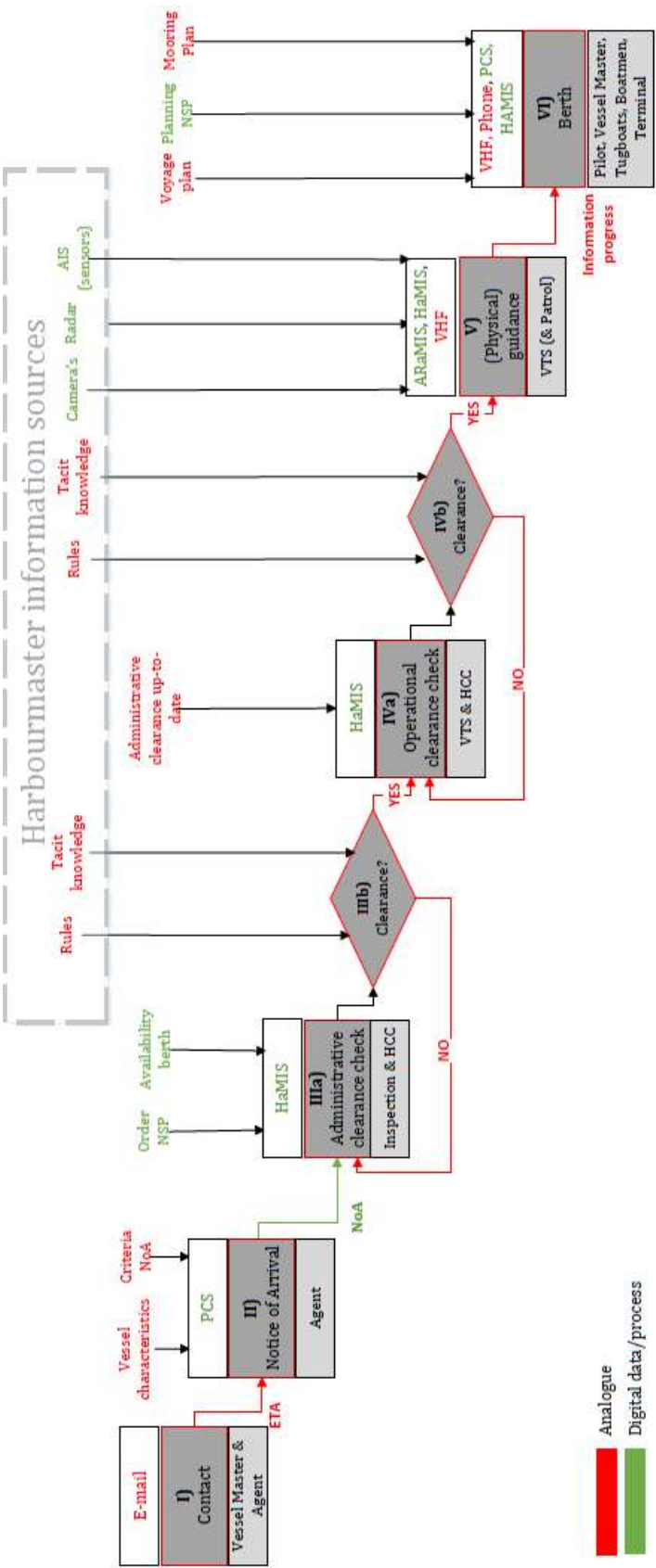


Figure 5.4: Analogue and digital data and processes in the port-call-process

IV Operational clearance

How? The operational clearance check is done by the VTS and HCC, based on digital information, and communicated to the vessel master analogue.

Potential for digitalisation: The data for the operational check is mainly coming from information in ARaMIS, traffic information. Based upon the vessel traffic in the port and along the future voyage of the vessel, the VTS decides to give operational clearance. Information therefore is provided digital.

Potential for automation: Again, the operational clearance has potential to be automated on all four levels. The actual traffic image can be gathered automatically (Level 1) after which the traffic intensity is analysed (Level 2). Now a decision can be made whether or not the vessel can continue its voyage, which can either be accepted or declined by the working VTS operator (Level 3), or even be implemented by the system (Level 4). With autonomous vessels, it is even possible to sail into the Pilot Maas area automatically if the clearance is provided. A clearance would not even be necessary anymore if the vessel has the actual traffic data and knows how to handle upon this data.

V (Physical) guidance.

How? The check for physical guidance is done by the HCC based on information provided digitally. The physical guidance itself is done by a Patrol Vessel, that communicates with the vessel master by VHF. Guidance from the VTS is done analogue via VHF.

Potential for digitalisation: All information that is needed for the check for physical guidance can be provided digitally. Communication with the PV and vessel master, is also eligible for digitalisation. However, the physical guidance itself cannot be done digitally. The guidance by the VTS operator can be digitalised by for instance implementing new software allowing the VTS operators to give notifications to the vessel master via computer.

Potential for automation: It would be possible to have the check for physical guidance done automatically, since all information already is digital. The guidance itself, can be automated as well by means of an autonomous Patrol Vessel. The PV receives information from the HCC and VTS about the position and voyage planning of the vessel (Level 1). It analyses this information and makes a forecast of the location of the vessel and the procedures it need to follow (Level 2). The PV can sail towards the vessel and guides it along the channels (Level 4).

Once information is digitalised, guidance done by the VTS operator can be automated on all four levels as well. All information to make decisions is gathered automatically (Level 1), and based on analysis of this information, business rules and machine learning, information for traffic guidance can be retrieved (Level 2). A decision for guidance advises can be given which can be implemented by either the VTS operator (Level 3) or automatically (Level 4). Furthermore, for an autonomous vessel, vessel traffic guidance is done via software and sensors (AIS, radar) on board or on shore of the vessel and other vessels. Based on

VI Berth of the vessel.

How? After pilot embarkment, the voyage plan is discussed analogue and transmitted via VHF. The ordering of NSP is was transmitted digitally. Via VHF, instructions for the boatmen and tugs is transmitted by the vessel master. The boatmen know based on their skills and tacit knowledge the exact method to moor the vessel safely and according to the mooring arrangements set by the shipping company. The exact location of the vessel to be moored, is often not known by the NSP.

Potential for digitalisation: With the right software the voyage plan and mooring plan can be transmitted digitally between all parties. This requires information about the exact mooring location, vessel characteristics, traffic intensity and availability of the quay. Collaboration between the shipping company, terminal, crew, vessel master and NSP about the exact mooring location of the vessel (e.g. manifold number, hawsehole number, length of the vessel) could be digitalised. However, digitalising tacit knowledge of the boatmen and tug organisation can be difficult.

Potential for automation: This last step in the port-call-process, is (partly) eligible for automation as well. Voyage planning can be automated in the first two levels. Based on big data analysis the voyage planning can be automated. Information needed for mooring the vessel can be provided to all parties automatically. Based on tacit knowledge of the NSP and routine procedures depending on the type of berth, vessel class and size, mooring arrangement and type of quay, an advice for the best way to moor the vessel can be provided. Automation can be applied up until Level 3. Level 4 automation requires the use of autonomous vessels that automatically transmit information with sensors in the port. No pilotage will be required and the vessel itself makes a real-time voyage planning. Due to the weight and

robust movements, the traffic in the port and dense surroundings, the help of tug-boats will always be required (Negenborn, 2018; Tabak, 2019). Autonomous tugboats can be an option. Mooring the vessel autonomous will be difficult due to the weight in combination with the weather and lateral forces (Neef, 2018; Tabak, 2019).

As is described, almost all processes and information have potential for digitalisation and automation. The techniques mentioned are advanced sensors to provide more accurate, real-time data, big data analysis to replace tacit knowledge, software supporting autonomous decision-making and implementation, and autonomous vessels. All techniques require availability of data and the collaboration between organisations in the port-call-process to share their data.

5.3.2. AUTONOMOUS VESSELS

Autonomous vessels (AVs) are considered as a major disruption having impact in the port-call-process and operations of the Harbourmaster (Cappelle, 2017; Chong, 2018; Devaraju et al., 2018; Dorsser, 2018; SmartPort, 2018). The impact of autonomous shipping in the port is related with the phasing of the introduction. This section briefly discusses the potential areas of impact of the introduction of AVs. More information related with the phasing and impact can be found in the interviews with experts in appendix C and in the literature review of autonomous vessels in appendix E.7.7.

Developments in technologies as well as regulations concerning AVs strongly determine the phasing and speed with which autonomous vessels can be introduced (Cappelle, 2017; Danish Maritime Authority, 2017; Rolls-Royce, 2016). For the Harbourmaster, the main impact of AVs lie in the infrastructure and in the role of the organisation. Depending on these two aspects, the HM will or will not be able to receive autonomous vessels in the Port of Rotterdam. The main adjustments in infrastructure required are improved internet, a Shore Control Centre (SCC) and an automatic mooring system (Devaraju et al., 2018; SmartPort, 2018) & (appendix E.7.7). Availability of data and collaboration between organisations in the port-call-process is perceived highly important since this is required for safe operations, better scheduling and data-analytics (Devaraju, 2017; Tabak, 2019).

Besides the impact of autonomous vessels on port-infrastructure, AVs will affect the role of the Harbourmaster as well (SmartPort, 2018). Autonomous ships are expected to appear incrementally. Depending on the readiness of technologies and their fault free track record, higher levels of autonomous vessels with reduced manning will be sailing (Rylander & Man, 2016). The most challenging period is this transition phase, where autonomous ships will need to operate in mixed environments together with traditional vessels (Chong, 2018). From the Harbourmaster, with his key tasks of facilitating a safe and efficient port-call-process, a different role might be required to be able to achieve his objectives. AVs also might lead to different tasks within the departments of the Harbourmaster. The areas of impact focus on operations, technique and training Chong (2018). Physical and VHF communication is limited which might result in inaccurate assessments of emergency situations (IALA, 2016). Information between the vessel or SCC will be mainly available through digital format. The increase of reliance of software and digital information increases the need of ICT systems to interact with autonomous vessels (Chong, 2018). To manage this change, new VTS procedures and systems might be required. In addition, adequate training is required for the VTS operators to be familiar with the operational risks and functions of the new systems. The role of the Harbourmaster's organisation might change from actively managing vessel traffic to analysing data (Tabak, 2019). More threats (and opportunities) are discussed in the following section.

5.3.3. OPPORTUNITIES AND THREATS

Digitalisation and automation offer opportunities and cause threats. The level of impact as well as the speed of the trend both are uncertain and hard to predict. This section alleviates on some of the opportunities and threats found in literature and mentioned by experts during interviews.

By solving current problems, opportunities of digitalisation and automation can be found in increases in productivity and efficiency. Digitalising the communication between the vessel master and other parties can help to decrease the amount of miscommunications due to (technical) failures, such as language barriers, poor sound quality of VHF or wrong channel (Mansson et al., 2016). In addition, according to the HCC operators and NSP, if planning information between the parties is digitalised and atomised, a reduction of the delays can be obtained (Groot et al., 2019; Maan, 2018; Neef, 2018; Tabak, 2019). If the ETA is accurate and re-

liable, an improvement in planning can be obtained with all activities involved in the arrival of vessels (Smart-port, 2018). This accuracy will be strengthened even more if the availability of NSP and terminal occupancy know are known to all parties involved (see appendix C). Furthermore, by digitalising data needed for clearances and automate them, clearances can be provided sooner due to a decrease of inaccuracies (Maan, 2018).

In addition, digitalisation and automation might lead to a safer port-call-process. The execution of some functions by computers, has or can now be extended to functions humans cannot perform as accurately or reliably as the machines (Parasuraman et al., 2000). The concept of autonomous shipping is driven by safety of live, costs and the shortage in seafarers (Chong, 2018; Rylander & Man, 2016). A study Rothblum found that 75%-96% of marine casualties are caused by some form of human error. Since intelligent algorithms for collision avoidance approach the collision avoidance problem in a more objective way than humans, expected is that autonomous vessels may possibly suppress the navigational error to zero (Chong, 2018). However, no research has been done to analyse the amount of collisions that has been avoided by humans (Tabak, 2019). In addition, digitalisation Autonomous shipping offers opportunities such as improvements of efficiency and safety. More advanced digital communication systems might be used to support the arrival of autonomous shipping so that more information about intention and status can be send and received (Seignette, 2019; Tabak, 2019). This data can be send to vessels so that it can respond to weather conditions immediately and calculate a better route.

On the other hand, threats lie in the uncertainty of the impact, the unforeseen, but also in new risks that come along with this trend such as IT dependence and cyber attacks. Automation, in each of the four levels, can come along with the loss of certain manual capacities. IT dependence is associated with the risk that one forgets how to do certain things and becomes unable to operate without IT automation and digitalisation (Newell & Marabelli, 2015). This might pose issues especially when technology stops working in a higher level of automation, with algorithmic decision-making. When supervising or undertaking human activities involves highly threatening outcomes, a technology failure might lead to for instance collisions. A concrete example is the tacit knowledge that is used in several processes of the port-call-process. When transforming this knowledge into business rules and when decisions are made based on algorithms, it is likely for problems to occur since no one in the organisations understands why some decisions are made (Newell & Marabelli, 2015). This also applies to autonomous vessels. It was found that the extent of consequences resulting from non-navigational accidents such as fire or structural failure of the vessel, are expected to be much larger for unmanned (autonomous) vessels. This is due to a lack of crew to assess and carry out damage control (Chong, 2018).

Furthermore, because of connectivity between sensor devices, there is also the potential of chaos occurring if everything stops working for everyone simultaneously. The importance of this threat therefore lies in the fact that automation cannot just replace human activity but rather changes it, often in ways unintended and unanticipated by the designers of the automation (Parasuraman et al., 2000). As a result, this might pose new coordination demands on the human operator and requires different competencies of the human operator. Another threat which should be mentioned is the threat that the benefits from investments in digitalisation and automation might be delayed or minimised by a lack of support from the staff to implement the new working processes. This threat should be mitigated by 'change management' in the organisation(s) (Seignette, 2018).

5.3.4. RELATION BETWEEN DIGITALISATION AND AUTOMATION AND THE OBJECTIVES

The potential for digitalisation and automation in the port-call-process, the threats and opportunities can be visualised in a causal diagram to illustrate the impact on safety and efficiency in the port-call-process. This diagram depicts the causal relations between all factors relevant for the process and objectives on an aggregated level (Enserink et al., 2010). Figure 5.5 shows this diagram including the relations between the factors of the port-call-process (in grey) and the main objectives (in green). Digitalisation and automation, as external factors, are represented in a blue oval. In addition, the cooperation between organisations in the port-call-process is an important external factor in the port-call-process as well since it is an essential element in the potential of digitalisation and automation and linked to the availability of data (see section 5.3.1). Where a causal relation labelled with a plus denotes a positive correlation, a minus denotes a negative correlation.

As can be seen in the causal diagram, 'availability of data', contains three incoming factors of which one

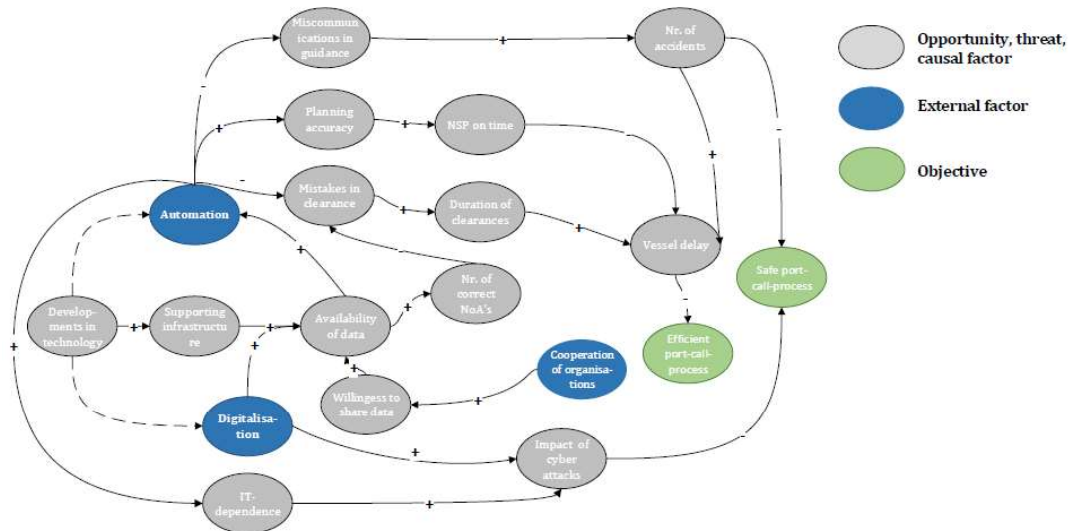


Figure 5.5: Causal diagram impact of digitalisation and automation in the port-call-process

is digitalisation, and two outgoing arrows of which one leading to automation. With this amount of causal relations it is an essential factor when defining the impact of digitalisation and automation. The more data is available, the more processes can opt for automation (on specific levels as mentioned in section 5.2.3. Since automation requires less additional steps (performed by humans), it could improve planning accuracy and reduces mistakes in clearances and miscommunications in guidance. Thereby it reduces the number of accidents, improves the times the NSP are on time and decreases the duration of clearances and by doing so the total amount of vessel delays will decrease contributing to a more efficient port-call-process. Additionally, when more data is available, the Notice of Arrival is more likely to be correct which reduces the mistakes made in clearances and therefore the duration of clearances and vessel delay.

Furthermore, less miscommunications in traffic guidance result in a decrease in the number of accidents leading to a safer port-call-process. However, the risk of cyber-attacks will remain and by having more data digitalised the impact of such an attack will be higher leading to a less safe port-call-process (Haugehatveit et al., 2018). This is intensified by IT-dependence when processes are automated.

5.4. CURRENT INITIATIVES

The Harbourmaster has noticed the trend of digitalisation and automation. In an attempt to anticipate to this trend, the initiative 'Harbour Master Next Generation' was established in 2018. The programme is initiated to prepare the Harbourmaster for changes, to make use of opportunities that will arise and to explore what is needed to maintain a safe and smooth environment (Dorsser, 2018). The resilient strategy that is designed in this research, is more likely to be implemented if it fits in the current operations of the Harbourmaster. The vision, as discussed in chapter 4 as well as the current projects and programmes of the Harbourmaster are therefore important to take into account.

The HMNG-programme has arisen from the fact that much of the knowledge of Harbourmaster employees in the operational area (HCC, VTS, Inspection, Patrol vessels), that is stored in the minds of operators, will disappear in the next five to ten years due to ageing. This tacit knowledge is of huge importance for maintaining a safe and efficient flow of traffic in the port. In order to adapt to this change in staff, the HMNG initiative has started to optimise the current processes by implementing new technologies and services.

The HMNG initiative is focusing on the following main processes:

- **Supervision and maintenance.** Transparent and interactive supervision will contribute to a clean and secure port for users. The aim is to create business rules based on tacit knowledge of HCC and Inspection operators.

- **Planning.** Vessel- planning and services will be automatised to relieve both the captain and vessel from administrative burdens. A concrete tool that has been used to digitalise data is Avanti. The Avanti web-portal is aiming on 'master data' such as depth and admission clearances, helping helps the Harbour Master to manage his nautical port information in a way that it is always available, up-to-date and accessible to all port users (Havenbedrijf Rotterdam, 2016a). This improves accuracy and speed of the administrative and operational clearances, that are now based on analogue rules (Seignette, 2018).
- **Traffic Management.** Rotterdam will be the world first port ready to receive all kinds of shipping; autonomous, smart ships and conventional ships. To this aim, in 2018 the Harbourmaster has started with analysing all sensors currently available in the PoR, in order to examine where improvements can be made (Oostenbrugge et al., 2018). In addition, the HMNG initiative keeps track on all innovations in sensors, radars, and AIS that is made.
- **Incident prevention.** Incidents will be disputed together, fast and adequate, while humans will be protected from potential risks. The aim is to have accurate prediction models that sign critical situations on forehand.

5.5. CHAPTER SYNTHESIS | TREND OF DIGITALISATION AND AUTOMATION

Digitalisation and automation is a trend that affects the institutions, the port-call-process and the Harbourmaster organisation itself. In this chapter an answer is provided to the third sub-question 'How might the trends of digitalisation and automation affect the current the port-call-process?'

Digitalisation and automation have a direct impact in the port-call-process. Where digitalisation is the transition of analogue data and tacit knowledge to digital information, automation is by means of digitalisation, acquire data and human tacit knowledge so that the system can replace (partially to fully) human labour. These definitions result in the distinction of four levels of impact of digitalisation and automation in the six sub-processes as defined in chapter 3; in the acquisition of information, the analysis of information, decision support and decision implementation. Techniques that will have most impact are advanced sensors to provide more accurate, real-time data, big data analysis to (partially) replace tacit knowledge, software supporting autonomous decision-making and implementation and the use of autonomous vessels. All of these techniques, require availability of data and the collaboration between organisations in the port-call-process which is at this moment not obviously present in the port-call-process.

Opportunities of digitalisation and automation mainly lie in a reduction of current problems such as delays, miscommunications, mistakes in sailing or guidance, and planning inaccuracies, all contributing to a safer and more efficient port-call-process. Cyber attacks and IT dependence will have consequences for safety and require a change of the organisation.

At this moment the port-call-process and processes of the Harbourmaster still are mainly analogue and therefore directly affected by digitalisation and automation. An indirect impact can be found in three areas.

1. The impact on the capabilities of the Harbourmaster's organisation. The Harbourmaster is required to be flexible and agile enough to anticipate to the trend while still guide decision-making towards long-term-objectives. In addition, his role in the port-call-process might change.
2. The impact on the current port-call-process and applications. All six sub-processes and their applications such as IT infrastructure, sources of information and communication between organisation might change.
3. The impact on staff qualifications. Due to a change in the processes, new demands are posed on the human operators. New skills might be required such as data analytics or management by exception.

The Harbourmaster Next Generation programme is initiated to anticipate to changes caused by digitalisation and automation. The programme however has been set-up as an attempt to optimise current processes mitigate the negative effects of the ageing problem. A structured approach about the potential impact of digitalisation and automation towards the objectives is needed.

The specific impact in the port-call-process, including both opportunities and threats is uncertain. The speed at which developments in technology are applicable and the level of collaboration between the organisations are uncertainties affecting this trend. These uncertainties together with the conceptualisation of the port-call-process provide sufficient basis for the design of scenarios in chapter 6.

II

ANALYSIS

6

SCENARIOS FOR THE PORT-CALL-PROCESS

Serving as the second step of the DAPP-framework, in this chapter scenarios are developed. By doing so, an answer is provided to the fourth sub-question 'How can future scenarios contribute to a resilient strategy for the Harbourmaster in order to anticipate to digitalisation and automation in the port-call-process?'. The main uncertainties with respect to the impact of digitalisation and automation in the port-call-process and the objectives as conceptualised in the first phase of this research, serve as input for this chapter. The generation of the scenarios is performed according to the steps of Schwartz (1991). The result is a set of four scenarios relevant for the Harbourmaster that will be described at the end of this chapter.

Section 6.1 describes the approach used to develop the scenarios. After an elaboration of the characteristics of scenarios, the driving forces in the environment of the Harbourmaster and the port-call-process will be discussed. The driving forces with most impact that are highly uncertain lead to the establishment of the scenario logic. Section 6.2 provides the narratives of the four scenarios.

6.1. SCENARIO DEVELOPMENT

This section serves as building block for the construction of scenarios that contribute to resilient strategies. In section 6.1.1 is described how scenarios contribute to guarantee resilience as well as the method to construct them. Next the global trends are discussed and the key forces relevant for the local environment of the Harbourmaster are presented. Based on these key forces, the scenario logic is created.

6.1.1. SCENARIOS AS A TOOL TO GUARANTEE RESILIENCE

Scenarios are narratives about the future. They enhance a strategy's robustness by a better understanding of the risks involved with the substantial and irreversible commitments that come along with uncertainties. With their complexity, interactions and outcomes, the future can be unforeseeable. As described in chapter 2, a resilient strategy helps an organisation to survive, adapt and grow in face of changes due to uncertain trends. To design a resilient strategy, planning should therefore not be conducted against only one 'most likely' scenario, rather a set of scenarios should be used (Schoemaker, 1993). Based on this set of futures, the Harbourmaster can position himself and generate action strategies to react to their eventualities (Walker et al., 2001). By doing so, scenarios help in reducing risks and uncertainties in strategic decision making (Wise et al., 2014).

CONSTRUCTION OF THE SCENARIOS In his book 'The Art of the Long View: Planning for the Future in an Uncertain World', Schwartz outlines several steps to be followed in order to develop scenarios. According to Schwartz, scenarios are developed to help people emphasise in plausible futures. Enserink adds to this that the most important step when developing scenarios is the simple narrative that brings the scenarios to life (Enserink et al., 2017). Therefore it is recommended to seek data from many sources to build better scenarios (Schwartz, 1997). To do so, various studies about scenarios in the maritime sector and ports have been analysed (Carlan et al., 2017; Dorsser, 2015; Fang et al., 2018; Rijkswaterstaat, 2018; Seignette, 2006; SmartPort, 2018; Willeumier et al., 2018). In order for the scenarios to be useful and understandable by the Harbourmaster's organisation, the scenarios are verified and validated by experts of the TU Delft and the Harbourmaster's department (see appendix C).

6.1.2. DRIVING FORCES

The driving forces are the mega trends driving uncertainties in the context of the port-call-process. They shape the broader business environment the Harbourmaster is operating in. According to Schwartz, driving forces may stem from social, economic, political, environmental or technological trends (Schwartz, 1997). Some will be predetermined, others will be highly uncertain. This research is focusing on one of these uncertain factors stemming from technological trends; digitalisation and automation. As discussed in chapter 5, the impact of this trend has various levels and affects multiple areas of the port-call-process. Nevertheless, important is to acknowledge other mega trends that might affect the port-call-process as well. In 2016, the 'Nationaal Instituut voor de Scheepvaart en Scheepsbouw' (NISS) described the global drivers for the maritime sector towards 2050 derived from the key trends mentioned by Schwartz. This list consists of five driving forces. Additional forces found in future studies of governmental- and maritime organisations and expectations from various departments at the Port of Rotterdam have been assigned to one of these five driving forces:

- **Social-economic development.** The population is growing at around three per cent per year, doubling in size by 2030 (Longva et al., 2014). This combined with an expected economic growth resulting in an increase in trade will put pressure on the demand for seaborne transport. The volume of goods transported by ships and demand for the associated maritime services has grown steadily, resulting in the following sub-trends (Department for Transport, 2019; Fang et al., 2018):
 - Consolidation of shipping companies. The negotiation position of shipping companies is strengthened more and more by alliances and merges. This position is even further reinforced by the addition of considerable terminal capacity in the Hamburg-Le-Havre range (Port of Rotterdam, 2014).
 - Scale increase in container shipping sector. As a result, increasingly high volumes of cargo arrive on a steadily shrinking number of vessels. The expectation is that peak loads will become more prominent at the terminals and consequently the speed (and efficiency) at which cargo is put through via the Port's terminals will become important even more (Port of Rotterdam, 2014). Expected is the scaling up of the container sector will continue in the period ahead.
 - Increasing competition. The competition between European ports in the container sector is becoming even fiercer (Port of Rotterdam, 2014). International ports can no longer automatically assume that clients will opt for them based on location, width or water depth. In the end, the clients most important concerns are minimising emission levels and costs per transported cargo weight or unit. And they base this on their own chain, from warehouse to warehouse.
- **Formal institutions.** Changes come with new rules that might change the role of Port and influence the maritime sector. Since the Harbourmaster is a State division, his processes and procedures are bounded by the formal regulations the Government, the municipality of Rotterdam, the EU and the IMO have provided to him. Adaptions in this rules, for instance environmental restrictions or restrictions in tasks allowed to be performed by the HM, might affect the operations of the Harbourmaster enormously (Port of Rotterdam, 2014):
 - Stricter regulations towards the role of the Harbourmaster. The IMO is watching the Harbourmaster's operations more and more and restricting the Harbourmaster in interfering with the market forces in the port-call-process. The Harbourmaster's role is to facilitate the port-call-process and not to manage the vessel traffic by himself.
 - Upcoming regulations with respect to autonomous shipping. At this moment the IMO is focusing on autonomous shipping, and the responsibilities and regulations that come along with this trend. The questions are arising whether or not an autonomous vessel still is a ship? Is there a link to a flag state? Who is responsible for the vessel? New rules will be needed on ship safety, port state control and facilitation of maritime traffic (Van Hooydonk, 2016). The development of these correlations have a strong correlation with developments in technology towards autonomous shipping. If regulations are not supporting, autonomous shipping is not likely to become reality.
- **Geopolitical stability.** This covers the predictability of the political environment, when influencing factors such as geography, economics and demography have been taken into account. The actions of other countries have major influence on the shipping trade and therefore on the navigation in the Port of Rotterdam (NISS, 2016).

- Politics of other countries. When other countries change their political environment, this may have major consequences for the Port of Rotterdam. The latest example is the Brexit. Higher import tariffs may decrease the trade between the countries, and changing customs formalities require changes in the port community systems and lead to more waiting vessels in the port.
- Changing demography and trade. The maritime sector is significantly affected by the changing shape of world population (Department for Transport, 2019). Developing countries will see the greatest growth and might potentially shift trading patterns and demands for imports and exports. This may have consequences for the growth of trade and the throughput in the Port of Rotterdam (Port of Rotterdam, 2014).
- **Climate change.** Global warming and its effects is a topic that is gaining more attention the past decade. It is clear a global transition to a cleaner and greener maritime sector will impact the changing patterns of trade (Department for Transport, 2019).
 - Increasing role of shipping as transport modality. Shipping is the lowest-carbon mode of transport available and therefore has a crucial part to play in a sustainable future (Longva et al., 2014). In addition, zero-emission (autonomous) vessels are developed and are expected to be introduced within fifteen years from now (SmartPort, 2018). New port infrastructure such as charging stations might be needed. Expected is that these zero-emission vessels will be combined with autonomous vessels. The trend of climate change therefore is assumed to contribute to the development of autonomous vessels (automation).
 - Growing importance of high quality port operations. Due to availability of data and more efficient port operation, the nautical chain can be synchronised resulting in a precise vessel traffic path that optimises speed and thereby reduces emissions (NISS, 2016; Smartport, 2018). Synchromodality, the real-time exchange between transport modes, is plays an important role in the performance of a Port (Department for Transport, 2019).
- **Technology.** Over the next few decades, developments in ICT will revolutionise shipping and thereby create a more connected and efficient industry closely integrated with global supply chain networks (Longva et al., 2014). Further developments in ICT will cover a wide range of changes, from sharing of data between parties, transparency of data, autonomous decision-making to autonomous sailing.
 - Digitalisation and automation of processes. Due to digitalisation and automation, technologies are likely to emerge and change the maritime sector and the speed together with the level of impact is uncertain and hard to anticipate on (Department for Transport, 2019). Digitalisation and automation, as a specific part of this trend, is expected to affect the port-call-process on various levels and is the main force analysed within this research and is therefore labelled as a key force in the local environment of the Harbourmaster.
 - Autonomous shipping. With advanced ICT, vessels can be designed in such a way they can be remotely-operated from shore, or even fully autonomous. The development of autonomous vessels is intensified by the benefits of lower operational costs compared to conventional vessels due to the absence of crew, risks associated with human error and threats to crew safety (Department for Transport, 2019). In addition, due to smart planning tools, autonomous sailing leads to a reduction in emissions (Smartport, 2018).

These driving forces help to give a direction to the future scenarios of the Harbourmaster. Correlations between the forces and digitalisation and automation are identified. The social-economic developments together with climate change puts pressure on the Port operations. Accurate planning will be required leading to efficiency and safety. Regulations towards the trend of autonomous shipping affect the development of the technology. In addition regulations also limit the boundaries between which the Harbourmaster can position himself. From the driving forces, key forces affecting the port-call-process most can be derived.

6.1.3. KEY FORCES IN THE LOCAL ENVIRONMENT OF THE HARBOURMASTER

According to Schwartz, key forces in the local environment of the organisation need to be identified as they are important in the scenario logic (Schwartz, 1997). These consists of the uncertainties of digitalisation and automation in the port-call-process derived from the driving forces and the uncertainties that are mentioned in chapter 5.

- **Digitalisation and automation.** Many uncertainties come along with this main trend. Two of them have been identified as the most relevant uncertainties:
 - Level of impact. Digitalisation and automation might affect all of the sub-processes of the port-call-process as well as the required capabilities of the Harbourmaster's organisation and the staff qualifications. The severity of the impact is uncertain.
 - Speed of technology application. Developments in information technology, automation, big data analysis are gaining attention more and more. However, the speed with which these developments can be applied depends on all kinds of uncertain factors such as regulations, price, social embeddedness of digitalisation and automation, risk assessments and the willingness of organisations to test and implement the technology developments.
- **Port-call-process.** The port-call-process, is facing many uncertainties. As has become clear when conceptualising the process, both the role of the Harbourmaster and the cooperation of parties, are uncertain.
 - Role in vessel traffic management. The role of the Harbourmaster is to facilitate a safe and efficient port-call-process of vessels. By providing him with boundaries, he has given the public mandate to do so by the government. However, his position between those boundaries is uncertain.
 - Cooperation of organisations. The cooperation of parties as mentioned in chapter 3 and chapter 5, makes a significant difference in the performance of the port-call-process in matters of efficiency and safety. Due to planning, data sharing and transparency, a strong collaboration between the parties might result in a smooth vessel voyage. As turned out in the history of the relations between all organisations involved in the port-call-process, the willingness of these parties to cooperate is an uncertain element. Additionally, as is visualised in the causal diagram in figure 5.5, chapter 5, cooperation between organisation contributes to the availability of data which affects the impact of digitalisation and automation.

6.1.4. SCENARIO LOGIC

Now the driving forces and key forces in the environment of the Harbourmaster have been identified, the most critical uncertainties need to be identified in order to design the scenario logic. The scenario logic comprises the dimensions for the scenarios. These are factors whose outcomes are unpredictable, but will affect the system over time and therefore are essential to address for scenario development (Enserink et al., 2013).

For the construction of the scenario logic the speed of the applicability of developed technologies is mapped out against the cooperation of organisations in the port-call-process. Both of these factors are highly uncertain, and have extremes. They can either give a push to the opportunities of digitalisation and automation (which comes along with threats) or make changes hard to implement. It is no uncertainty technology is developing and will have an impact on the Harbourmaster's organisation. However, the level of the speed with which the developed technology is applicable is uncertain and depends on both formal- and informal institutions (acceptance and regulations). The level of impact is uncertain as well, but is considered to be more or less dependent on the speed of the applicability of technology. A low speed comes along with a lower impact of technology applicability, meaning only the first two levels of automation can be reached. A high speed of technology applicability means automation and digitalisation on all levels are possible. Due to the boundaries between which the Harbourmaster is allowed to operate, the role of the Harbourmaster is considered as a less uncertain element than the cooperation of organisations in the port-call-process. In addition, the impact of his role will not be as high since he has been given the task to facilitate a safe and smooth port-call-process, independent of changes in its environment. Based on the scenarios that will be derived from the logic, the Harbourmaster can choose to position himself within each of the scenarios. All other driving forces identified still have an influence on the port-call-process. Their influence is assumed to be constant in all scenarios.

The directions of 'speed of applicability of technology development' and 'cooperation of organisations', can be drawn in a system of axes. The X-axis represents the speed with which the technology is developing and ready to be applied. The dimension ranges from moderate applicability to rapid applicability. Technologies

can be applied in all sub-processes identified in chapter 3 on both digitalisation and automation as structured in chapter 5, section 5.2.3. The time range still is the same as defined in the scope; from now till 2050. A moderate applicability of developments in technology implies that the developments and applications of technology only allow digitalisation of data and automation on the first two levels; information acquisition and information analysis. In the scenarios with a rapid applicability of developments in technologies, automation of decision selection and action implementation can occur resulting in a digitalisation of processes. The Y-axis represents the level of cooperation of the organisations with respect to vessel traffic management in the port-call-process. The dimension of this factor varies from weak collaboration to strong collaboration. This results in orthogonal scenarios that do not overlap. The position of the scenarios in the matrix are shown in figure 6.1.

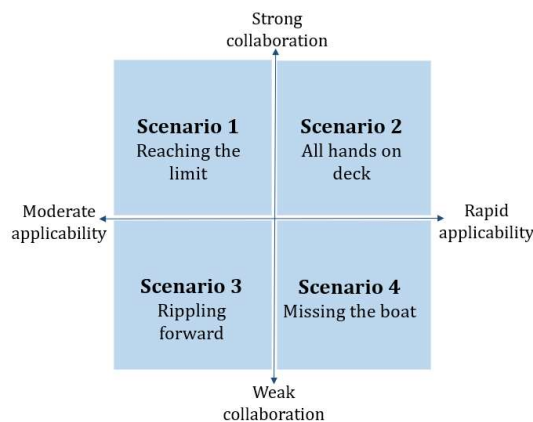


Figure 6.1: Scenario logic

The 'reaching the limit' scenario comprises a future in which there is a strong collaboration between all organisations involved, willing to help each other. However, technology is developing slow decreasing the efficiency that can be reached. In the 'all hands on deck' scenario, all organisations collaborate and seize opportunities of the fast developing technology to improve the port-call-process, but these new technologies come along with new challenges. In the third, 'rippling forward' scenario, compared to the previous scenarios, organisations in the port-call-process have their own interest and are not willing to work together. Compounded by the slow development of technology results in relatively low efficiency. The fourth scenario deals with a fast development of technology in combination with a low collaboration between all stakeholders. All organisations, can choose for themselves how they respond to the opportunities and threats the new technologies might bring and how they want to use it in the port-call-process.

6.2. FOUR SCENARIOS

Based on the scenario logic, four scenarios have been designed. To be used as an effective planning tool, they are written as absorbing, convincing stories that describe a broad range of alternative futures (Ogilvy & Schwartz, 2004). Problems that might occur and opportunities that arise in the scenarios can be identified and actions to avoid these problems or seize the opportunities can be designed (chapter 7 and 8). Information from interviews with experts (Appendix C) and the conceptualisation of the current port-call-process and impact of the trend strengthens narrative of the scenarios. Furthermore, studying underlying patterns can help to show how a system interacts (Ogilvy & Schwartz, 2004). Therefore the causal diagram showing the influence of digitalisation and automation on the port-call-process as presented in chapter 5, figure 5.5 serves as a powerful tool for exploring the logic of the scenario. To be able to use the scenarios, it is important they fulfil the requirements, and are accepted and understood by the organisation. Therefore the scenario logic has been verified and the scenarios have been validated by experts from the Harbourmaster's organisation and TU Delft (Seignette, 2018).

The stories evoke challenging questions, opportunities and threats concerning the areas of impact of digitalisation and automation as identified in chapter 5; the organisation of the Harbourmaster, current processes in the port, and the implications for the staff. This will be presented first followed by a more detailed description of the scenarios.

6.2.1. SCENARIO 1: REACHING THE LIMIT

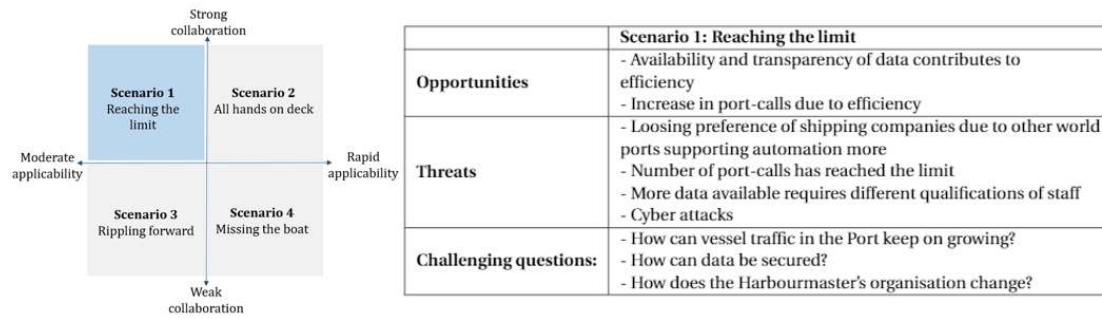


Figure 6.2: Characteristics of the 'reaching the limit'-scenario

Technology is developing slowly and enables organisations involved in the port-call-process to make the process more efficient. All organisations start digitalising analogue data which helps in registering potential areas for improvement. Developments in technology are offering opportunities to make the port-call-process more efficient. Yet, due to societal norms and values, risk assessments and safety standards, regulations prohibit the application of technology developments to a certain extend.

All organisations note the current problems in the port-call-process: miscommunications, planning inaccuracies and mistakes in clearances do not disappear. Collaboration between all organisations reduces these problems and thereby increases the efficiency in the port-call-process. Synergy is often mentioned as the key to success for everybody.

By doing so, planning of vessels can be optimised since agents, the vessel master and terminals are willing to provide a more actual Estimated Time of Arrival. This offers opportunities to improve processes within all organisations; pilots, tugs and boatmen can optimise their schedules based on the accurate ETA and real-time updates. A reduction of waiting time for vessels is achieved easily and therefore the Port is getting more and more preferred by shipping companies; time is money. Together everybody works to become one of the most efficient and safest port in the world! This draws the attention of shipping companies which results in a preference for the Port of Rotterdam. However, this improvement in combination with the worldwide increase in trade leads to more port-calls and therefore the relevance of accurate vessel traffic management to maintain high efficiency and safety levels.

Nonetheless, in this scenario restrictions in regulations concerned the application of technology developments are not evolving fast enough to keep up with the growth. Data analysis cannot be automated and no digitalisation of processes can be obtained. It looks like there is a limit to the efficiency that can be obtained.

6.2.2. SCENARIO 2: ALL HANDS ON DECK

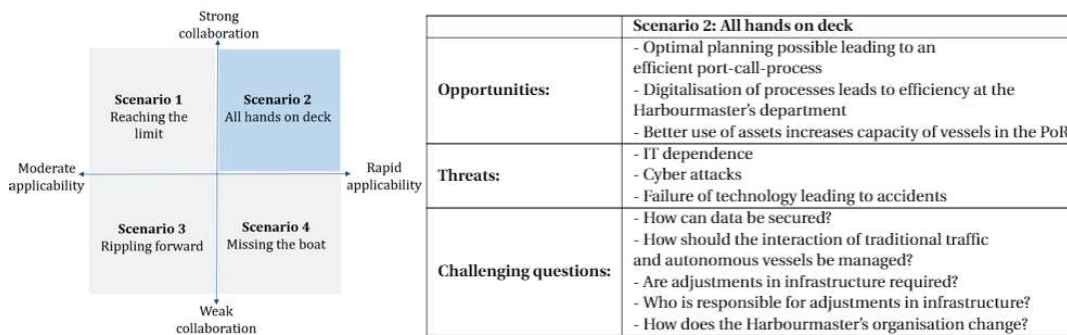


Figure 6.3: Characteristics of the 'all hands on deck'-scenario

Trust between organisations has returned and all parties acknowledge that collaboration in the port-call-process benefits all. Strengthened by a fast development in technology, this offers opportunities to combine the planning software systems of all parties. Availability of knowledge and transparency of data has become a fact of life and in the environment of the Harbourmaster practical applications of technology are visible. Social acceptance of automation is not an issue. Smart sensors enable real-time tracking of vessels on sea and in ports. Estimated Times of Arrival are adjusted automatically based on availability of pilots, tugs, boatmen and terminal capacity. Not only Maasvlakte 2 has automated terminals, all terminals are operating autonomously. In addition, updates from commercial parties (oil-prices) which used to put vessels for anchorages, are taken into account as well. Even further, data concerned availability of inland-barges, trains or trucks is accessible as well and the software system makes sure the best synchromodal planning will be executed. This will lead to Just-In-Time arrival of vessels and adjustments in speed resulting in a reduction in carbon emissions. In addition, regulations allow the use of drones which means physical inspections are not required anymore, resulting in less delay for vessels. The Port of Rotterdam will form part of an advanced and integrated supply chain by 2050.

Furthermore, regulations about unmanned shipping are established and the first autonomous vessels are reality. The tacit knowledge of NSP is all translated to business rules and therefore no pilotage, tugs and boatmen are needed. By advanced AIS systems and GPS sensors, collisions between vessels are avoided and the vessel can moor itself safely which seems to make traffic guidance dispensable. The vessel is monitored from shore-based control centres and in case of technical failures, a technician or mechanical engineer is sent to the vessel.

On the other hand, not all traffic is autonomous and the interaction between autonomous vessels, conventional vessels, and recreational traffic such as water-skis, rowing boats and small motor boats, is alarming. Abrupt human actions are unforeseeable by autonomous systems, vessels cannot stop or turn abrupt which might result in serious accidents. Thereby, failures of systems of autonomous vessels in the port environment can lead to collisions as well. The risk of serious consequences of cyber attacks increases as well and software infrastructure supporting the port-call-process can be hacked. Safe and efficient vessel traffic in the port-call-process cannot be guaranteed. High pressure is put on vessel traffic management and the responsibilities of the Harbourmaster!

6.2.3. SCENARIO 3: RIPPLING FORWARD

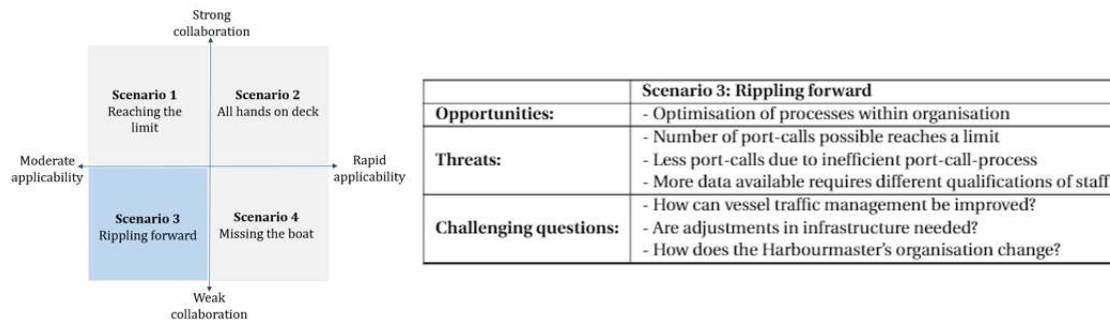


Figure 6.4: Characteristics of the 'rippling forward'-scenario

All organisations involved in the port-call-process are aware of the improvements in efficiency that can be obtained. However, everybody is scared to loose power and therefore not willing to cooperate. This leads to a transfer of tasks to the Harbourmaster. The HM is perceived as an enemy seeking for too much power in the port-call-process which is not his main duty.

With an eye on cost reductions and ageing staff, all organisations start to optimise their own processes. This optimisation is sparked by opportunities of new technology developments. The implementation of these new technologies though is slow, as regulations prevent the use of new technologies and the price of new innovations is too high. The applicability of autonomous vessels does not get off the ground due to insufficient risk assessments. Organisations are able to improve their own processes, but a lack of available and accurate data limits digitalisation and automation of data and processes. New technologies such as advanced AIS or accurate sensors measuring data autonomous cannot be implemented. Communication between parties still will be mainly analogue via VHF and phones. Strengthened by the use of wrong data and assumptions this may lead to more mistakes in planning, miscommunications and inaccurate ETAs, NOA's and clearances and therefore results in increasing delays for vessels. Due to these delays the amount of port calls decreases as shipping companies prefer surrounding, better performing ports.

The result is a port-call-process, that is moving forward slowly. External influences such as climate change, consolidation of shipping companies, scale increase of vessel sizes are serious challenges that require an integrated strategy, covering the whole port-call-process and effort from all organisations. In addition, potentials of digitalisation and automation should be addressed in order to maintain high quality port operations. Unfortunately the will to cooperate and solve issues is lacking.

6.2.4. SCENARIO 4: MISSING THE BOAT

	Scenario 4: Missing the boat
Opportunities:	<ul style="list-style-type: none"> - Optimisation of processes within the organisation - Overcome ageing problem within Harbourmaster's division
Threats:	<ul style="list-style-type: none"> - IT dependence - Incomplete and inaccurate data - Cyber attacks - Less port-calls due to inefficient port-call-process
Challenging questions:	<ul style="list-style-type: none"> - What is the right way to manage vessel traffic? - How can data be more available and reliable? - How can data be secured? - Are adjustments in infrastructure required? - How does the Harbourmaster's organisation change?

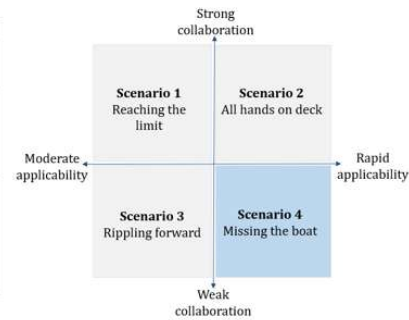


Figure 6.5: Characteristics of the 'missing the boat'-scenario

The relations between the organisations in the port-call-process are under high pressure. Many opportunities are available due to new technologies lying ahead to improve efficiency and safety in the port-call. However, the NSP, terminals and agents are not willing to share their data and knowledge. They stick to their own interests and have no trust in each other. History has proven that a collaboration between the parties does not work out in the best interests of the pilots, and terminals and shipping companies rather have their own collaboration. The availability of data is scarce leaving little opportunities for automation on all levels.

Technologies to improve, digitalise and automate processes within all organisations are available. Shipping companies invest in technology themselves. Highly specific GPS sensors, traffic forecast software and planning tools in combination with the consolidation gives the shipping companies a stronger negation position. Additionally, strong climate restrictions put pressure on Just-In-Time vessel traffic planning and in combination with soft regulations, investments in autonomous shipping are made and the first autonomous deep-sea vessels are constructed. Pilots, tugs and boatmen are making use of the technology developments as well and experiment with autonomous vessels to increase efficiency and reduce cost of labour.

All organisations digitalise and automate their own processes but due to a lack of collaboration, processes are not aligned and data is not accurate. This leads to a high risk of collisions. Frustrations, inaccurate planning and missed opportunities are the outcome. This is not unnoticed by shipping companies and they will rather call at another port. The opportunities are there, they only have to become reality.

6.3. CHAPTER SYNTHESIS | SCENARIOS FOR THE PORT-CALL-PROCESS

The objective of this chapter is to analyse opportunities, threats and challenging questions the future might bring in order to be able to design a wide range of actions contributing to a resilient strategy. This objective is reached by answering the sub-question 'How can future scenarios contribute to a resilient strategy for the Harbourmaster in order to anticipate to digitalisation and automation in the port-call-process?'. To cover a wide range of futures, strategy development should be conducted against multiple scenarios. Therefore four diverse scenarios are developed based on the most uncertain and relevant forces influencing the port-call-process.

The driving forces stem from five main trends mentioned in literature; social-economic development, regulations, geopolitical stability, climate change and technology. These forces interact and are dependent on each other. The factors whose outcomes are unpredictable and have a high impact on the port-call-process are essential to address for scenario development. These key forces are the speed at which the developed technologies are applicable (rapid or moderate) and the collaboration of organisations in the port-call-process (strong or weak). The speed of the applicability of developed technologies affects the level of digitalisation and automation that can be obtained. Other driving forces influence the port-call-process as well, but their direction is assumed to be constant in the scenario descriptions. However, these driving forces provide important information for the Harbourmaster concerning potential changes in his environment.

The scenarios can help the Harbourmaster in anticipating to possible futures and to be prepared and flexible to the unexpected threats, challenges and opportunities that an changing and uncertain environment might present. Thereby they contribute to the resilience of a strategy by generating a better understanding of the risks involved with changes in current operations that come along with uncertainties.

III

DESIGN

STRATEGY DEVELOPMENT

To design a resilient strategy roadmap for the Harbourmaster to anticipate to digitalisation and automation in the port-call-process, actions need to be defined. In this chapter actions are developed for the Harbourmaster based on the four scenarios described in chapter 6. The scenario descriptions all led to various challenging questions for the Harbourmaster in the areas of impact in the port-call-process and the organisation of the Harbourmaster. By designing actions relevant to deal with these challenges, an answer can be provided to the fifth sub-question 'What are effective actions the Harbourmaster can undertake to anticipate on the impact of the scenarios?'

A brainstorm-workshop called 'Resilient port-call-process 2050' with employees from different departments of the Harbourmaster has been organised to design concepts of actions to anticipate to the problems and opportunities in the scenarios. In section 7.1 the objectives of this workshop and the contribution to the final resilient strategy roadmap are discussed. The workshop contains several rounds and the results of each of these rounds is elaborated upon in section 7.2. In section 7.3 the results are transformed into specific actions that can be applied in the resilient strategy roadmap that is developed in chapter 8.

7.1. THE 'RESILIENT PORT-CALL-PROCESS 2050' BRAINSTORM WORKSHOP

Employees from the Harbourmaster's department are included in the process of action generation to guarantee support from the organisation. Active participation helps in the creation of actions and is considered important both for improving the knowledge base as for helping to develop actions fitting in the Harbourmasters working processes. Sharing these ideas for actions with others in a group session, turns out to have a cognitively stimulating effect of all individual employees (Nielsen, 2012).

7.1.1. A BRAINSTORM TO IDENTIFY ACTIONS

Brainstorming is an often used method to spark creativity of solutions (Coffey et al., 2003). Therefore, specialists with a thorough knowledge of the organisation and the critical issues to be addressed were invited to participate in a brainstorm-workshop. This workshop was called 'Resilient port-call-process 2050'. The participants have a diversity of knowledge, competences, experiences, age and education since this is proven to be a core factor in the advancement of innovative ideas (Campbell, 1960; Nielsen, 2012). All of them stem from a strategic department of the Port of Rotterdam.

To achieve the desired results of a brainstorm-workshop, a skilled facilitator is essential. The facilitators main role is to engage a group of participants in a social process of collaborative idea development (Nielsen, 2012). The facilitator should be knowledgeable about the process of the workshop while the participants are familiar with the content of it (Papamichail et al., 2007). To ensure that the workshop is productive, effective and efficient, various authors have described key factors relevant for facilitating a brainstorm-workshop in the preparation, execution and proceedings (Campbell, 1960; Coffey et al., 2003; Diehl & Stroebe, 1987; Kaner et al., 2007; Nielsen, 2012; Papamichail et al., 2007). When preparing and executing the 'Resilient port-call-process 2050' brainstorm-workshop, these theories and practical tips and tricks were used. More information about the participants and the facilitation of the workshop can be found in appendix E.

7.1.2. OBJECTIVES AND SET-UP

The design of the workshop is determined by the input needed to establish a resilient strategy roadmap. A detailed description of the set-up can be found in appendix E. The following objectives have been defined for the brainstorm-workshop:

1. Get insight into opportunities and problems in the scenarios,
2. Identify various actions the Harbourmaster can take to prevent or respond to problems and to seize opportunities in all four scenarios,
3. Verification of contribution of the actions to long-term-objectives, safety and efficiency, as defined in chapter 4,
4. Assign actions to a date and put them in a sequence, in order to be useful for a roadmap,
5. Get insight in the preferred scenarios and actions to reach these scenarios.

The first round is created to discover both potential problems and opportunities that can be seized in all four scenarios. Opportunities are developments that can help in achieving the objectives, while problems are developments that can harm the extent to which the objectives can be achieved (Haasnoot et al., 2013). In the second round concepts of actions are identified to address the problems and to seize the opportunities. In the third round these concepts are rated based on their potential impact to safety and efficiency. The fourth round lets the participants assign the conceptual actions to a time-period to discover the starting period and possible sequences. The last round aims on identifying the preferred scenario for the Harbourmaster.

7.2. RESULTS OF THE ‘RESILIENT PORT-CALL-PROCESS’ BRAINSTORM-WORKSHOP

The results of the brainstorm-workshop are based on the rounds elaborated upon in section 7.1.2, and further elaborated and visualised in appendix E.

7.2.1. ROUND 1. PROBLEMS AND OPPORTUNITIES

To structure the results, each scenario is represented on a poster and divided into cells related with the areas of impact as identified in chapter 5. The cells vessel traffic management (VTM) and infrastructure (Infra) represent the current system and applications and the ‘organisation’-cell (Orga) represents the organisation of the Harbourmaster. One cell is left empty to support own thoughts and interpretations. The participants are not aware of the problems and opportunities that are identified in chapter 6. Per scenario, the participants brainstormed about potential problems and opportunities in the port-call-process. They wrote down at least 5 problems on post-its and assigned them to one of the cells on the poster of the corresponding scenario.

In total, thirty-four problems and seventeen opportunities are identified. Most problems are identified in Scenario 3: Rippling forward (weak collaboration and slow development). According to the participants most problems might occur in vessel traffic management and within the organisation of the Harbourmaster. This might give an indication of the perceived level of agility of the Harbourmaster. If the Harbourmaster’s organisation would have been perceived as flexible and adaptable, the chance problems would be identified due to changes in his environment might be less. Most opportunities were found in the scenarios with a weak collaboration between organisations.

Table 7.1: Amount of problems and opportunities identified in round 1

	Problems					Opportunities				
	VTM	Infra	Orga	Other	Total	VTM	Infra	Orga	Other	Total
1: Reaching the limit	3	2	4	0	9	1	2	2	0	5
2: All hands on deck	0	2	3	2	7	1	1	0	4	6
3: Rippling forward	5	2	3	2	12	0	1	2	0	3
4: Rock the boat	3	1	2	0	6	0	0	1	1	2
Total	11	7	12	4	34	2	4	5	5	16

It is difficult to draw conclusions from these numbers, since problems might be overlapping. Therefore table 7.2 shows the problems and opportunities that were found. A more detailed description of the problems and opportunities can be found in appendix E.

Table 7.2: Identified problems and opportunities

		Problems	Opportunities
Scenario 1: Reaching the limit	VTM	- No system harmonisation - Inefficiency - Misunderstandings	- Stable port-call-process
	Infra	- Lacking behind - Less influence HM on P-C-P	- Trust in proven technology - Less risks
	Orga	- Frustrations technology application - Loss of support - Pressure on organisation - Tempo growth too high	- Strong organisation - Leader in collaboration
	Other	-	-
Scenario 2: All hands on deck	VTM	-	- Market-leader global standards
	Infra	- Cyber risk - Investments pay-back	- Improvements (such as optimise asset management)
	Orga	- Organisation not agile - IT dependence - No basic knowledge of digitalisation	-
	Other	- Tension acceptance technology - Traditional sectors cannot keep up	- Transparency towards customer - Better competitive position PoR - New business models - Efficiency improvement
Scenario 3: Rippling forward	VTM	- Inefficient port-call - Limit port-calls reached - Pilots draw own plan - More mistakes - More accidents	-
	Infra	- Inefficient investments - Less investments	- Savings on investments
	Orga	- Pressure on Harbourmaster - Harbourmaster has no role - Pressure on competitive position	- High employment rate - Less resistance labour unions
	Other	- No increase in sustainability - Societal and European pressure	-
Scenario 4: Rock the boat	VTM	- Inefficiency - Different standard procedures - Limited exploitation of technology	-
	Infra	- Too much different systems	-
	Orga	- Organisation not agile enough - Pressure on organisation	- Optimise own processes
	Other	-	- Insights in developments

A few aspects in table 7.2 draw attention:

- Causalities can be found between the problems. In the first scenario, in VTM, 'inefficiency' is an effect of 'misunderstandings' and a 'lack of system harmonisation'. In the third scenario the same problem occurs. 'More mistakes' and 'more accidents' lead to an 'inefficient port-call'.
- In all scenarios, participants noted 'pressure on organisation' or 'organisation not agile' enough, as a problem. This means that according to the participants it is difficult for the Harbourmaster's organisation to adapt to changes in his environment given these scenarios. This presses the need for a resilient strategy.
- 'Inefficiency' is often mentioned as a problem. This is alarming since one of the objectives of the Harbourmaster is 'to facilitate an efficient port-call-process'.

- ‘Cyber risk’ and ‘IT dependence’ are only considered as problems in Scenario 2. Since Scenario 4 also deals with a rapid applicability of developed technologies it would be expected these problems would occur in this scenario as well. This can be explained by the set-up of the workshop as elaborated in Appendix E. A different explanation is that the duration of the brainstorm was too short and participants did not have enough time to think of all possible problems.
- Most of the problems and opportunities identified by the participants correspond with the ones identified in chapter 6. However, the threats and opportunities that come along with more availability of data: ‘IT dependence’, ‘inaccurate data’, ‘relevance of cyber security’, and ‘increasing efficiency due to more available data’ were not identified by the participants. This could be the reason of unfamiliarity with the topic or the perception that availability of data is not relevant in the port-call-process.
- In addition to the previous item, no problems were found for VTM in Scenario 2. This is unexpected since the interaction of traditional and autonomous vessels might lead to unforeseen situations as described in chapter 6, section 6.2.2. A possible explanation is that the participants do not expect autonomous vessels to be allowed as long as safety cannot be guaranteed (Seignette, 2018).

7.2.2. ROUND 2. ACTION

The aim of this round is to assemble a rich set of possible concepts of actions. By means of a brainstorm, conceptual actions are identified to address the problems and seize the opportunities identified in the first round. The problems are written down on sticky notes and assigned to the corresponding sticky notes with problems or opportunities. The same group-setting as in the first round was used. Table 7.3 shows all concepts of actions identified per scenario.

Table 7.3: All concepts of actions identified during round 2

		Conceptual action
Scenario 1: Reaching the limit	VTM	- Harmonisation of systems - Standardisation of data - Invest in stability of systems
	Infra	- Development of infrastructure
	Orga	- Invest in stability of systems - Maintain acceptance - Communicate open and transparent - Collaborate with stakeholders to develop - Participate in identification of technical opportunities - People management, the employee central
	Other	- Work on stakeholder support for role of leader - Pressure on government for technology applicability
Scenario 2: All hands on deck	VTM	-
	Infra	- Stimulate and facilitate start-ups and innovations - Invest in digital competencies - Invest in data analysis - Modify investment policy - Invest in cyber risk management together with other organisations
	Orga	- Invest in maintenance of data bases, algorithms and systems - Different staff qualifications - Social dialogue with the environment - Invest in risk management together with other organisations
	Other	- Help traditional sectors to develop themselves.
Scenario 3: Rippling forward	VTM	- Break monopoly of pilots - Risk management - Use authority to create rules
	Infra	- Work together to improve trust - Different business model
	Orga	- Develop technology in collaboration with other ports - Invite new players (Amazon) to improve efficiency

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		Conceptual action
		<ul style="list-style-type: none"> - Reduction on port tariff - Enforce organisation to only execute tasks they are obliged to do - Increase service level for clients
Scenario 4: Rock the boat	VTM	<ul style="list-style-type: none"> - Adjust own strategy where needed - Publish standards used by the PoR - Generate more insight in unused opportunities together with clients
	Infra	- Experiment with clients and technology firms
	Orga	- Use authority as enabler
	Other	-

In total, 36 concepts of actions are identified to avoid problems or to seize opportunities. These concepts can be applied in the resilient strategy roadmap immediately:

- Some of the conceptual actions, such as 'experiment with clients and technology firms', involve collaboration between different organisations. Since these concepts are not concrete and have no stakeholder, they are not ready to be applied in the pathways yet.
- Some of the concepts are quite similar or have overlap. For instance, 'publish standards used by the PoR' could be a method to achieve 'standardisation of data'.
- Noticeable is that many conceptual actions are very general and can be interpreted differently. An exact tool or method is often lacking. Examples are 'invest in stability of systems', 'communicate open and transparent' or 'use authority to create rules'. These conceptual actions raise the questions 'Which systems should be invested in?', 'Via what medium and about what should be communicated?' or 'What should the rules be about?'. This might be the cause of the strategic mindset of the participants.

Due to the reasons mentioned above, the concepts of actions first have to be processed in order for them to fit in the strategy roadmap. This is done in section 7.3.

7.2.3. ROUND 3. RELEVANCE OF THE CONCEPTUAL ACTIONS

This round serves as a verification of the conceptual actions generated in the second round and to exclude the concepts that would not benefit either efficiency or safety in the port-call-process. This is an important step added in the DAPP framework used in this research. The possible future situations are compared with the specified objectives (safety and efficiency in the port-call-process) to identify possible gaps. The concepts are rated with a plus sign and a letter 'S' or 'E' if they contributed respectively to a Safe or/and Efficient port. A minus and zero represented a decrease and equal causality.

None of the conceptual actions scored negative on both efficiency and safety. According to the participants, 'invest in cooperation projects and digital competencies', 'invest in risk management with all VTM actors' and 'invest together with other organisations in competencies and organisation of reducing cyber risk' have a negative impact on efficiency and 'break monopoly of the pilots', has a negative impact on safety. When designing pathways for the resilient strategy roadmap, such actions should not be all part of the same strategy.

7.2.4. ROUND 4. SEQUENCING OF THE ACTIONS

In the fourth round, the conceptual actions were assigned to a time-period. Participants were asked to replace the sticky notes from the scenario-posters to the timeline from the year 2019 to 2050. The results of this round give an indication for the assembling of the pathways in the resilient strategy roadmap. The introduction of the autonomous vessel is considered as a disruptive innovation (see chapter 5, section 5.3.2) and the estimation of its introduction is therefore marked on the timeline. The period of introduction of the autonomous vessel is based on the nearest (most extreme) point in future that is found in literature or expressed during interviews (see appendix C). Based on reports from the research institute Smartport, which is a consortium of the PoR, Deltalinqs, TNO, Deltaris, Erasmus Universiteit and Delft University of Technology, an estimation

of the introduction of autonomous vessels has been made (SmartPort, 2018). They state fully autonomous ships will be operating within fifteen years from now. Since no earlier period of introduction of autonomous vessels has been found, the introduction of autonomous vessels has been presented on the timeline in the year 2035.

Table 7.4: Sequencing of actions

Period	Conceptual action
2019-2022	<ul style="list-style-type: none"> - Increase service level clients - Pressure on government for technology applicability - Participate in identification of technical opportunities - Invest in stability of systems in VTM and organisation - Risk management - Invest in digital competencies - Different staff qualifications - Invest in data analysis - Enforce organisations to only execute the tasks they are obliged to do - Experiment with clients and technology firms - Harmonisation of systems - Standardisation of data - Stimulate and facilitate start-ups and innovations - Work on stakeholders support for role of leader
2022-2025	<ul style="list-style-type: none"> - Publish standards used by the PoR - Development of infrastructure - Communicate open and transparent - People management 'the employee central' - Invest in maintenance of data bases, algorithms and systems - Invite new players (Amazon) to increase efficiency - Invest in risk management with all other organisations - Use authority to create rules
2025-2027	<ul style="list-style-type: none"> - Reduction of port tariff - Develop technology in collaboration with other ports - Invest in cyber risk management together with other organisations - Modify investment policy - Adjust own strategy where needed - Social dialogue with the environment - Different business model - Generate more insights in unused opportunities together with clients - Use authority as enabler
2027-2030	<ul style="list-style-type: none"> - Help traditional sectors to develop themselves - Collaborate with stakeholders to develop - Work together to improve trust - Break monopoly of the pilots - Implementation of new rules
2030-2035	-
2035-2040	-
2040-2050	-

According to the participants, most of the concepts should start in the period between 2019 and 2022. No actions were placed on the time-line in the period from 2035 onward. This irregular division can be explained by the fact that all participants stem from strategic departments of the Port of Rotterdam. With this strategic mindset, most concepts are focused on long-term policies or strategies. Examples are 'lobbying for the application of autonomous vessels', 'development of new business-models' and 'gain more knowledge about data'. Specifications of these concepts could be 'create an autonomous vessel lobby team', 'make a new soft-

were program for faster clearances' or 'establish a dedicated data team'. Another possible explanation for the distribution of actions can be found in the first round. Since no problems (and subsequently actions) were focused on the introduction of autonomous vessels, the addition of the introduction of autonomous vessel in 2035 on the timeline did not make any difference.

7.2.5. ROUND 5. PREFERENCE OF SCENARIO

The last round focused on identifying the preferred scenario. The preference of the scenarios was decided upon by voting.

The collaboration between organisations in the port-call-process was perceived as most important aspect having the most impact on the efficiency in the port-call-process. According to the participants, with a strong collaboration, both scenarios with a moderate applicability of technology as well as rapid applicability of technology could work. Therefore the preferred scenarios are Scenario 1 and Scenario 2. Everybody agreed that Scenario 3 is the least preferred scenario. Scenario 4 was considered a scenario where the Harbourmaster's role would be as a controller of the port-call-process.

7.3. DESIGN OF ACTIONS

This section is aimed at transforming the conceptual actions into concrete actions for the Harbourmaster suitable to apply in the resilient strategy roadmap. Figure 7.1 shows the steps that are needed to do so. First the conceptual actions are aggregated based on their content. In section 7.3.2, specific, tangible examples of actions are derived.

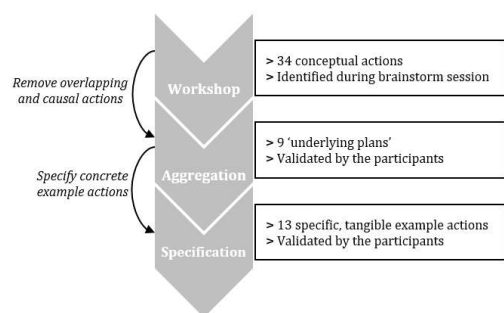


Figure 7.1: Stepwise design of actions

7.3.1. AGGREGATION AND CLASSIFICATION OF ACTIONS

This section focuses on aggregating conceptual actions that have a similar content or a causal relationship. Therefore the actions are grouped according to their underlying plan, or aggregated factor. This is the factor covering all the actions in the same group. This grouping, is done by the researcher and therefore is a subjective interpretation. Table 7.5 represents the list of the eight aggregated actions. Further elaboration on the aggregation of actions can be found in appendix E.

Table 7.5: Aggregation of actions

Conceptual actions	Aggregated actions
<ul style="list-style-type: none"> - Standardisation of data - Publish standards used by PoR 	1. Standardisation of data
<ul style="list-style-type: none"> - Invest in maintenance of data base, algorithms, and systems - Invest in stability of systems - Harmonisation of systems - Invest in data analysis - Risk management - Invest in reducing cyber risk 	2. Invest in data and systems

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Conceptual actions	Aggregated actions
<ul style="list-style-type: none"> - Development of infrastructure - Invest in digital competencies - Develop technology in collaboration with other ports 	3. Development of infrastructure
<ul style="list-style-type: none"> - Participate in identification of technical opportunities - Stimulate and facilitate start-ups and innovations - Generate more insight in unused opportunities together with clients - Experiment with clients and technology firms - Pressure on government for technology applicability 	4. Identify technical opportunities
<ul style="list-style-type: none"> - Maintain acceptance within organisation - Communicate open and transparent - People management, the employee central - Invest in maintenance and stability of the organisation - Different staff qualifications - Adjust own strategy where needed 	5. Change management
<ul style="list-style-type: none"> - Collaborate with stakeholders to develop - Work on stakeholder support for role of leader - Social dialogue with the environment - Work together to improve trust in infrastructure - Invest in risk management together with other organisations - Help traditional sectors to develop themselves 	6. Stakeholder management
<ul style="list-style-type: none"> - Use authority to create rules - Reduction on port tariff - Enforce organisations to execute only the tasks they are obliged to do - Use authority as enabler - Break monopoly of pilots 	7. Control
<ul style="list-style-type: none"> - Increase service level for clients - Invite new players (Amazon) to improve efficiency - Different business models - Modify investment policy 	8. Other

Using aggregation as a method to structure qualitative results, contains several risks. Firstly, the conceptual actions identified by the participants in the workshop might have been misinterpreted by the researcher (Estabrooks et al., 1994). This might lead to wrong conclusions resulting in an incorrect classification of actions with respect to their 'underlying plan'. In addition, taking only aggregated actions into account could result in unintentionally dismissing the concepts that do satisfy the requirements for a suitable action. To mitigate these risks, firstly the aggregated actions have been validated with the participants. Secondly, the aggregated actions are specified to assure no relevant actions are lost. This is done in the following section.

7.3.2. SPECIFICATION OF ACTIONS

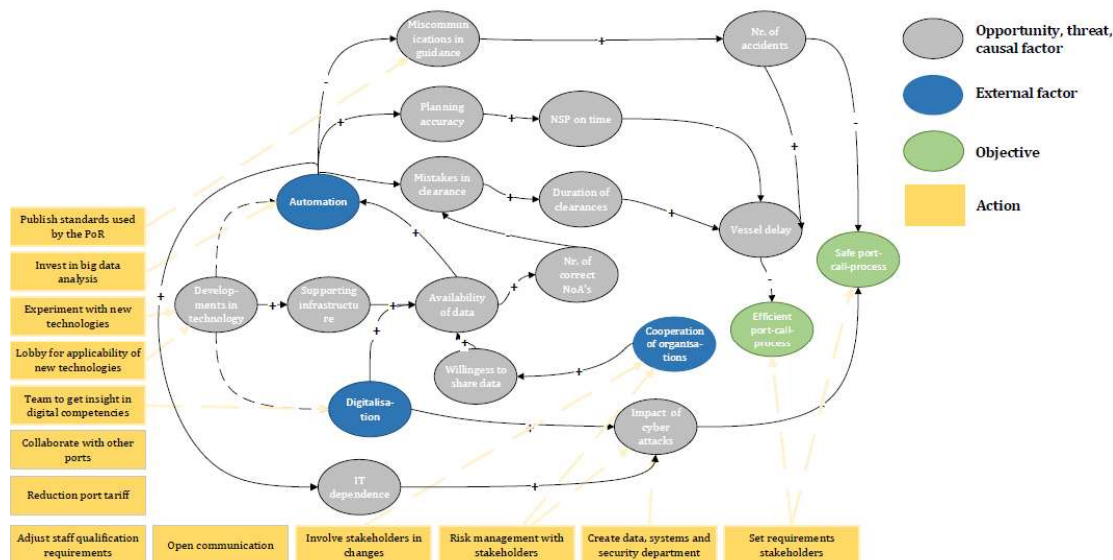
This section focuses on the specification of the aggregated actions in to concrete, tangible actions to be implemented by the Harbourmaster. From each of the aggregated factors, one or two specific actions are derived, based on the conceptual actions as designed in the brainstorm-workshop. An elaboration of the reasoning behind the specification of actions can be found in appendix E.

The resulting list of thirteen actions serves as example of actions that can be applied in the resilient strategy roadmap. Different specified actions derived from the aggregated factors can be applied as well. However, to give a clear overview in the resilient strategy roadmap a limited amount of actions is preferred. The resulting list of actions has been validated with Raymond Seignette (Seignette, 2019). Table 7.6 shows the list of actions that will be used in the resilient strategy roadmap. The starting period of the actions is based on the sequencing of the conceptual actions illustrated in section 7.2.4.

Table 7.6: From aggregated actions to usable actions

Aggregated action	Concrete actions	Starting period
Standardisation of data	- Publish standards used by PoR	2022-2025
Invest in data and systems	- Create 'data, systems and security' department - Maintain tacit knowledge by means of investing in big data analysis and algorithms	2019-2022 2019-2022
Development of infrastructure	- Get insight in digital competencies with dedicated team - Start collaboration with other ports	2019-2022 2025-2027
Identify technical opportunities	- Experiment with new technologies - Lobby for applicability of new technologies	2019-2022 2019-2022
Change management	- Communicate open and transparent - Adjust staff qualification requirements	2022-2025 2019-2022
Stakeholder management	- Actively involve NSP terminals, and shipping companies in changes - Discuss risks with all stakeholders	2027-2030 2025-2027
Control	- Reduction of port-tariff - Enforce organisations to act upon requirements Harbourmaster	2025-2027 2019-2022

The causal diagram presented in chapter 5, is used to illustrate the impact of the actions in the port-call-process. Figure 7.2 shows all thirteen actions (yellow rectangles) of which nine have a direct impact on the port-call-process (outgoing arrows). The action 'break monopoly of pilots' has not been taken into account as a strategy since it scores negatively on the safety in the port-call-process according to the participants of the workshop (see section 7.2.3). The action 'Other' has not been taken into account for further strategy development since the variety of actions is too broad.

**Figure 7.2:** Areas of impact of the strategies

Not all actions have a direct impact on the port-call-process but focus on the impact of digitalisation and automation on the organisation of the Harbourmaster. By doing so, these actions reduce the negative or uncertain effects of potential problems or other actions. In the Dynamic Adaptive Policy Pathways Framework, Haasnoot and Kwakkel classified the types of actions into four groups (see chapter 2). Mitigating actions reduce the likely adverse effects of a plan, hedging actions spread or reduce the uncertain adverse effects of a plan, seizing actions seize the available opportunities and shaping actions reduce failure or enhance success.

All actions are explained and classified according to these types and described next.

- **Publish standards used by the Port of Rotterdam**

At this moment, all ports apply their own standards and local rules within the port-call-process. Standardisation of data and processes contributes to efficiency and digitalisation of the port-call-process. The Port of Rotterdam can push this standardisation by publishing all standards they use. An example is the development of digital standards for the exchange of safety and traffic information. This is a mitigating strategy since it reduces the adverse effects of misunderstandings (in guidance) and inefficiency due to different standard procedures of all organisations.

- **Create 'data, systems and security' department**

Several of the identified actions, stress the importance of the software, systems and data supporting the port-call-process. A new department aimed at generating and maintaining this data and the systems therefore is a tangible action. By analysing the enormous amount of data available, insights can be gained in the areas of the port-call-process where many mistakes and delays take place. This action can therefore be classified as a seizing strategy. In addition, with the enormous amount of data becoming available, the risk of cyber-attacks increases. 'Risk management' of data was mentioned several times during the workshop. The new department could also be responsible for managing the risk and potential impact of cyber attacks. This strategy is therefore a hedging strategy as well. It reduces the uncertain effects of the amount of available data.

- **Invest in big data analysis**

Many of the actions that take place in the processes of a port-call, are based on years of experience. With an eye on the ageing of many employees, this tacit knowledge will be lost. The positive impact of digitalisation and automation can be accelerated when all data available is made digital, big data analysis can be used to gain more information and parts of tacit knowledge can be transmitted into algorithms (Polanyi, 1996). This action can contribute to automation of processes on different levels of automation (chapter 5) and is classified as both a hedging- and seizing strategy.

- **Team to get insight in digital competencies**

As has been mentioned in chapter 5, many processes, data and information exchange are analogue. Digitalisation and automation might benefit the port-call-process on several areas (chapter 5, section 5.3.3). To seize these opportunities, first research needs to be done to find out which processes and data can opt for digitalisation. By creating a dedicated team for this task, this action has a stakeholder and has been made concrete. An example of digital competencies are sensors and systematic monitoring systems that will enable greater transparency in shipping. This includes sensors in quay walls measuring the occupancy to make better use of existing capacity, more advanced AIS sensors or software to digitalise clearances. This action can be classified as a seizing strategy.

- **Collaborate with other ports**

Collaborating with other ports could increase efficiency in the port-call-process when it is combined with other strategies. For instance by sharing the Actual Time of Departure or sharing information about (dangerous) goods or people on board of the vessel, clearances can be provided faster. Digitalisation of data and processes can contribute to this collaboration. Also, experiments of technology (e.g. autonomous vessels, drones, sensors) can be done together and helps to achieve comprehensive results of these experiments faster. By working together with other ports knowledge is shared which reduces the uncertain effects of other strategies (hedging strategy) and opportunities can be seized (seizing strategy).

- **Experiment with new technologies**

The identification of new technologies contributes to the development of technologies suitable to be implemented in the port-call-process in order to reduce problems or seize opportunities. Experimenting with new technologies is a concrete strategy helping to identify suitable technologies and stimulate innovation and developments in technology (Thomke, 2003). When the Harbourmaster is actively participating in these experiment he can steer the experiments to contribute to results that are most valuable to him. This action can be classified as a seizing strategy.

- **Open communication**

Digitalisation and automation will impact the organisation and require changes in the Harbourmaster's

organisation. To create support for new action plans and organisational changes, the employees of the Harbourmaster have to be involved in changes. Important for them is to understand the need for the Harbourmaster to anticipate to the changes and the potential for success (Lenssen, 2014). By communicating transparent and open with the organisation the chance of failure of implementation of actions is reduced. Therefore this action can be classified as shaping.

- **Adjust staff qualification requirements**

Due to digitalisation and automation, working with and understanding of data is becoming more important in daily tasks and procedures. Digitalisation skills are in short supply. To anticipate to the trend and to reduce uncertainties, important is to build in-house capabilities by adjusting the staff qualification requirements and retrain the staff. According to McKinsey&Company consultants, the goal should be to create a centre of excellence with skilled staff that understand all aspects of digitalisation and automation (Markovitch & Willmott, 2014). Understanding of the data and software is essential to avoid IT dependence (shaping & mitigating strategy).

- **Involve stakeholders in changes**

This strategy implies that the Harbourmaster is responsible for involving all relevant parties in the port-call-process in the actions he takes to anticipate to digitalisation and automation. A way to do so, is to create cross-functional units that bring together all parties (including IT developers) involved in the port-call-process. Monthly meetings can be organised to align the objectives and interests of all parties, to exchange tacit knowledge and to discuss the impacts of the actions of the Harbourmaster. This strategy contributes to stakeholder support for the Harbourmaster's actions (hedging action). In addition this strategy can contribute indirectly to an increase in efficiency of the port-call-process. When stakeholders are willing to cooperate, data can be shared and the processes of all organisations can be synchronised. Individual planning tools of all organisations can be combined leading to an accurate planning of vessel arrivals and terminal occupancy's. This can contribute to a precise schedule of pilots, tugs and boatmen (seizing action).

- **Risk management with stakeholders**

Risk management is important to reduce the likely adverse and uncertain effects of digitalisation and automation and to maintain an efficient and safe port-call-process (hedging and mitigating action). Discussing the risks of the trend on Vessel Traffic Management with all parties involved in the port-call-process leads to an understanding of the negative impacts of this trend on the processes of all organisations. Stakeholder might understand the importance of cooperation in order to maintain safe and efficient processes for all organisations. In addition, combining knowledge of experts on the different fields might lead to a comprehensive inventory of all possible risks and thereby might reduce the impact of cyber-attacks. It reduces the change of failure and therefore can be classified as a shaping strategy.

- **Reduction of port-tariff**

Reducing the port-tariff is a strategy aimed at reducing the uncertain adverse effects of digitalisation and automation; decreasing efficiency leading to a decreasing competitive position of the Port of Rotterdam. This action therefore is a mitigating action. It can also be classified as a hedging strategy since a reduction of the port-tariff might lead to an increase in port-calls. The strategy by itself does not directly contribute to the established KPIs.

- **Set requirements for stakeholders**

The position of the Harbourmaster in the port-call-process is unique since he can use his authority to have a leading and controlling role in Vessel Traffic Management. He can choose to have a more intensive and active role in the coordination of the planning of vessel traffic and the deployment of the NSP (Seignette, 2010). Enforcing all organisations to obey to the rules of the Harbourmaster might contribute to an efficient and structured organisation of the Port-Call-Process. With this controlling role, both uncertain and negative effects can be reduced and therefore this strategy can be classified as mitigating and hedging.

- **Lobby for applicability of new technologies**

Innovations in technology can contribute to the benefits digitalisation and automation might bring. Both in the internal processes of the Harbourmaster and the port-call-process. However, formal institutions slow down the speed of the applicability of technology. By lobbying for the approval of the

applications of technical innovations, benefits of digitalisation and automation such as efficiency improvements can be obtained faster and chances of failure are reduced (shaping strategy).

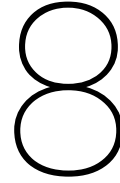
7.4. CHAPTER SYNTHESIS | STRATEGY DEVELOPMENT

In this chapter actions are identified to address the problems and opportunities of the four different scenarios. Thereby an answer is provided to the fifth sub-question 'What are effective actions the Harbourmaster can undertake to anticipate to the impact of the scenarios?'. Effective actions are actions that either seize opportunities or address problems in the areas of impact in the four scenarios. Conceptual actions have been designed by experts from different departments at the Port of Rotterdam in a brainstorm-workshop. Since they have a thorough knowledge of the organisations and the critical issues to be addressed contributing to the usability of actions the developed actions are perceived to be relevant.

In the workshop, actions are rated based on their relevance with respect to the long-term-goals of the port-call-process and their sequence in time is determined. The action 'break monopoly of pilots' has a negative impact on safety and is therefore left out in further analysis. Actions related to investing in data and systems and the identification of technical opportunities contribute negatively to efficiency and should therefore be combined with other actions in the resilient strategy roadmap. According to the participants almost 80% of the actions is supposed to start in the upcoming 10 years. This is due to the fact that the identified actions are almost all strategically-oriented actions.

Aggregation and specification of the actions, resulted in a list of thirteen examples of actions (see table 7.6). Most actions directly affect the impact of digitalisation and automation in the port-call-process. Many problems were found in the organisation of the Harbourmaster which might imply a lack of agility of the Harbourmaster to respond to changes in his environment. Therefore some actions focus on the impact of digitalisation and automation on the organisation and staff qualifications. These actions mitigate uncertainties and reduce the chance of failure. The list of actions, together with their sequence and starting period can be used in the resilient strategy roadmap that is designed in chapter 8.

There should be noted that the outcomes of the workshop might be more reliable and extensive if more participants would attend from more diverse departments. Also, by increasing the duration of the workshop a different set-up would lead to more consistent results where all participants are able to brainstorm about all scenarios. Lastly, the list of thirteen actions serves as examples based on the aggregated actions. The categories of aggregated action can be used as an indicator for the Harbourmaster when designing actions.



RESILIENT STRATEGY ROADMAP

This chapter is focusing on the development of the roadmap. With the final roadmap, resilient strategies for the Harbourmaster can be identified. In this chapter, an answer is provided to the final sub-question ‘How does the strategy roadmap for the Harbourmaster look?’. Based on the scenarios for the port-call-process, actions are identified to avoid problems and to seize opportunities of digitalisation and automation in four types of scenarios. The final thirteen actions developed in chapter 7 serve as input for the roadmap.

First the design of the basic roadmap is elaborated upon. Adaption pathways are assembled by looking at the sequence of actions as well as their sell-by-dates. In section 8.1.1 the sell-by-date of all actions per scenario is discussed. Next the sequence of the actions is determined. Combining information from these sections, a resilient strategy roadmap is designed in section 8.2. Based on the scenarios and the preference of the Harbourmaster, a different perspective of the role of the Harbourmaster in the port-call-process can be chosen. Two different perspectives, the facilitator and controller, are proposed in section 8.3.

8.1. PATHWAY DESIGN

In this section the steps taken in order to design the final pathways for the resilient strategy roadmap are discussed. Pathways can be assembled in different ways. Figure 8.1 shows the elements required for the design of pathways. Essential is to determine the sell-by-date and the sequence of the actions. The sequence in time has been established during the ‘resilient port-call-process 2050’ brainstorm-workshop (section 7.1). However, the sequence of the actions with respect to their correlations has not been investigated yet. Some actions might only be beneficial if combined with other actions and might even increase the sell-by-date of other actions. In addition, actions that are already part of current projects and programmes might be more likely to be implemented first. This first section therefore focuses on determining the sell-by-date of the actions (section 8.1.1), as well as their sequence (section 8.1.2).

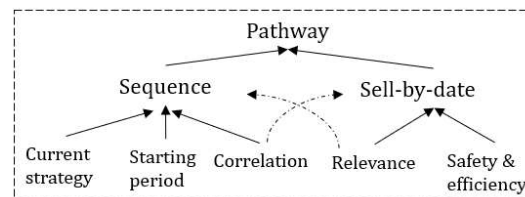


Figure 8.1: Qualitative approach of designing pathways

8.1.1. SELL-BY-DATE

When an action is no longer able to meet the definition of success, a new action is activated (Haasnoot et al., 2013). This adaption tipping point or ‘sell-by-date’, is an essential element for a pathway (Kwadijk et al., 2010). After reaching this point, additional actions are needed and the pathway emerges in order to still be able to meet the specified objectives.

The sell-by-date will be established for the thirteen action developed in chapter 7. In the Dynamic Adaptive Policy Pathways approach, a computational scenario approach is used to assess the distribution of the sell-by date of several actions across a large ensemble of transient scenarios (Haasnoot et al., 2013; Kwakkel et al., 2015). Since this study is a qualitative study, the sell-by-date is an assumption based upon literature and ex-

expectations of experts at the Harbourmaster's department. The sell-by-date differs per action and is defined by looking at the expected contribution towards long-term-goals and the relevance of the action. The contribution towards long-term-objectives has already been roughly determined during the 'resilient port-call-process 2050' brainstorm-workshop, after which all actions negatively affecting these long-term-objectives have been sorted out. However, the relevance of an action depends on the speed of applicability of technology (rapid or moderate) and the level of collaboration (weak or strong) and therefore is scenario-dependent. As was shortly addressed in the conclusion of chapter 7, actions can be divided based on the area of impact of digitalisation and automation they focus on. Therefore in this chapter, a distinction has been made between five types of actions that aim on mitigating, hedging, seizing or shaping the impact of digitalisation and automation. The types are: organisational actions, process-related actions and one action aimed at the staff qualifications.

Table 8.1 shows the sell-by-dates of the actions.

Table 8.1: Sell-by-dates of actions in years

	Reaching the limit	All hands on deck	Rippling forward	Missing the boat
1. Invest in big data analysis and algorithms	20	10	20	10
2. Create 'data, systems and security'-department'	>30	10	>30	10
3. Communicate open and transparent	>30	20	>30	20
4. Lobby for applicability of new technologies	10	>30	10	>30
5. Set requirements for stakeholders	x	x	>30	>30
6. Reduction of port-tariff	10	10	10	10
7. Get insight in digital competencies	>30	20	>30	20
8. Experiment with new technologies	20	>30	20	>30
9. Publish standards used by PoR	15	15	15	15
10. Risk management with stakeholders	>30	10	x	x
11. Involve stakeholders in changes	>30	>30	x	x
12. Collaborate with other ports	>30	>30	>30	>30
13. Adjust staff qualifications	>30	20	>30	20

The explanation of the sell-by-date per type of action is as follows:

- **Organisational actions.** Organisational actions are actions that are implemented within the organisation of the Harbourmaster and are aimed at the potential impact of digitalisation and automation on the capabilities of the Harbourmaster. These actions have a duration that differs per scenario. In the scenarios with a rapid applicability of technology, a more disruptive impact on the organisation is expected since opportunities and threats of digitalisation and automation might arise earlier.
 - Invest in big data analysis. To be able to seize opportunities digitalisation and automation might offer, it is important to analyse the increasing amount of data that becomes available in order to see where improvements can be made. Again, especially in scenarios with a rapid applicability of technology this action is perceived relevant. On the other side, this action might come along with the risk of IT-dependence which will potentially negatively affect safety of the port-call-process. Therefore the sell-by-date is estimated to be around twenty years in the rippling forward scenario and around ten years in the all-hands-on-deck scenario. However, if combined with adjusted staff qualifications, the sell-by-date of this action can be extended as will be elaborated upon in section 8.1.2.
 - Create 'data, systems and security'-department. With the emerging trend of digitalisation and automation, the need for data-security arises. Especially in scenarios with a rapid applicability of technology this action is perceived relevant. Therefore the sell-by-date of this action is 10 years in these scenarios and 30 years in the scenarios with a moderate applicability of technology, since it contributes to safety and efficiency but is not as relevant in these scenarios.
 - Communicate open and transparent. This action is not contributing to efficiency and safety by itself. However, with the expected impact of digitalisation and automation, the Harbourmaster is required to change his operations. By communicating open and transparent, the support from

the organisation will remain which might avoid other actions from failing. This action fits in all scenarios, however in scenarios with a rapid speed of applicability of technology the relevance of this action is sooner since a more disruptive impact on the organisation is expected. The sell-by-dates of this action therefore are the same as the 'adjust staff qualifications'-action.

- Lobby for applicability of new technologies. To be able to seize opportunities of digitalisation and automation, this action is relevant in all scenarios. However, in scenarios with a moderate speed of applicability of technology it might be more beneficial to start this action earlier to seize opportunities of digitalisation and automation. Therefore the sell-by-date is estimated around 10 years for these scenarios and 30 years for the 'all-hands-on-deck'-scenario and the 'missing-the-boat'-scenarios.
- Set requirements for stakeholders. In scenarios with a strong collaboration of organisations in the port-call-process, it would not be necessary to set requirements for stakeholders. Therefore this action is only applicable in the 'reaching the limit'- and 'all hands on deck'-scenario. By setting requirements for the other organisations in the port-call-process the Harbourmaster can guarantee safety and efficiency for the entire scope of this research.
- **Process-related actions.** The process-related actions involve all actions that are aimed at the impact on the current port-call-process and the applications. Digitalisation all analogue data and automating processes might require different software and IT-infrastructure. In addition, these actions might affect the institutional environment of the Harbourmaster and the port-call-process. By collaborating with stakeholders opportunities might be seized and problems might be overcome in an earlier stage. The process-related actions are:
 - Reduction of the port-tariff. The reduction of the port-tariff is an action not contributing to long-term-objectives by itself, but mitigating the likely adverse and uncertain effects of other actions. Reducing the port-call tariff therefore is an action that can be implemented at any time. However, the expectation is that it will only contribute on reducing the negative external effects of other actions for a period of maximum 10 years (Seignette, 2018).
 - Team to get insight in digital competencies. The first step of digitalisation of processes, is digitalisation of data (see chapter 5). In the scenarios with a fast applicability of technology, the expectation is that at some point in time all data and processes are digitalised and this action does not contribute to the long-term-objectives anymore. Therefore the sell-by-date of this action is assumed to be around twenty years in the 'all-hands-on-deck'-scenario and the 'missing-the-boat'-scenario and thirty years for the other scenarios.
 - Experiment with new technologies. Even though this action contributes to the long-term-objectives, its relevance is expected to be higher in scenarios with a moderate applicability of development of technology. The benefits of digitalisation and automation might be used earlier when experimenting leads to positive results. Therefore the sell-by-date of this action in the 'rippling forward scenario' and 'reaching the limit' scenario is estimated around twenty years.
 - Publish standards used by the Port of Rotterdam. Publishing standards used by the Port of Rotterdam might decrease miscommunications between organisations and is therefore an action that increases safety and efficiency in all scenarios. Based on previous experiences with publishing standard estimated is that it takes around 15 years to standardise most safety aspects (Seignette, 2019)).
 - Risk management together with all stakeholders. Risk management together with stakeholder is expected to have a positive impact on efficiency and safety as well but is perceived more essential in a rapidly changing environment due to digitalisation and automation. The time it takes to create a risk management team together with stakeholder is around ten years (Seignette, 2018). Therefore the sell-by-date is set on over thirty years for the 'reaching the limit'-scenario and for the 'all-hands-on-deck'-scenario it has been set on ten years. However, this action is only applicable in scenarios 1 and 2 since a collaboration between stakeholders is required.
 - Involve all stakeholders in changes. Since involving all stakeholders in changes has a positive effect on both efficiency and safety for the entire period of the scope of this research, the sell-by-date has been set for over thirty years. However, this action is only applicable in scenarios 1 and 2 since a collaboration between stakeholders is required.

- Collaborate with other ports. Collaborating with other ports does not directly affect the long-term-objectives. However, collaboration is useful to seize opportunities or overcome problems of digitalisation and automation in an earlier stage.

- **Staff-related action.** This action is aimed at anticipating to the new demands that are posed on the human operators in the port-call-process that might require new skills. This action is not contributing to efficiency and safety by itself. However, due to the impact of digitalisation and automation on the required skills of the staff, this action is essential to anticipate to the changing environment, especially in scenarios with a rapid applicability of technologies. In these scenarios, there will be a more disruptive impact on the organisation requiring a different set of skills from the organisation. This action is expected to contribute to both safety and efficiency for the entire scope of the scenarios. Since this action is more relevant in scenarios with a rapid applicability of technology, the sell-by-date for these scenarios is estimated to be 20 years.

Table 8.1 and the explanation of the sell-by-dates shows most of the actions contribute to the long-term-objectives. This might be the reason of the set-up of the brainstorm-workshop in which actions were rated on their contribution to the long-term-objectives and subsequently the actions that scored negative were sorted out. Therefore the relevance of the actions is determinant for establishing the sell-by-dates of the actions. Some of the sell-by-dates are correlated with other actions that will cause an extension of the sell-by-dates.

8.1.2. SEQUENCE

The next step is to determine the sequencing of actions. This is done by looking at the correlations of actions, the current strategies and the starting period. Also the relevance of the actions as elaborated upon in the previous section is taken into account. The sequencing in time (starting period) has already been done by the participants of the brainstorm-workshop (see section 7.2.4) and will be used in the roadmap. First the correlation between the actions will be discussed. Next the actions that are already part of current projects are elaborated upon.

CORRELATION

There are four actions that do not directly contribute to the long-term-objectives which are: collaborate with other ports, reduction of the port-tariff, adjust staff qualification requirements and open communication. However, these actions might contribute to an extension of the sell-by-dates of other actions, or might even be crucial for other actions to succeed. Based on the classification of the type of actions as defined in chapter 7, section 7.3.2, the interdependence of the actions can be determined. An overview is given in Table 8.2.

Table 8.2: Correlations of actions

Action	Type	Correlated to action:
1. Invest in big data analysis and algorithms	Seizing Hedging	2, 3, 8, 13
2. Create 'data, systems and security'-department	Seizing Hedging	2, 5, 10
3. Communicate open and transparent	Shaping	1, 2, 7, 8, 13
4. Lobby for applicability of new technologies	Shaping	8
5. Set requirements for stakeholders	Mitigating Hedging	10, 11
6. Reduction of port-tariff	Mitigating Hedging	-
7. Get insight in digital competencies	Seizing	3, 13
8. Experiment with new technologies	Seizing	1, 2, 3, 4, 13
9. Publish standards used by the Port of Rotterdam	Mitigating	-
10. Risk management with stakeholders	Mitigating Hedging	12

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Action	Type	Correlated to action:
11. Involve stakeholders in changes	Seizing Hedging	-
12. Collaborate with other ports	Seizing Hedging	10
13. Adjust staff qualifications	Mitigating Shaping	1, 2, 3, 7, 8

As can be seen, there are five actions (number 1, 2, 3, 8) that are correlated with each other and all seize opportunities of digitalisation and automation or mitigate and hedge the negative uncertainties involved with other actions. A combination of these actions could increase the impact of the action and make it more resilient. In case one of the actions does not lead to the desired results, a shift to a different correlated action can be made.

‘Adjust staff qualifications’ affects all these five actions. This is the only actions that focuses on the impact of digitalisation and automation of change of requirements of the staff and is therefore an essential action to be taken into account in the design of the resilient strategy. This is a shaping action to reduce failure of the correlated actions. When one of the five above mentioned actions is chosen, it should therefore be combined with the adjustments of staff qualifications. The reasoning is that without staff who understands the effects and potential of digitalisation and automation, actions aimed at adapting to this trend are likely to fail. An assumption is that this action will increase the sell-by-date of action 1 and 7 with approximately 10 years.

‘Communicate open and transparent’ is also classified as a shaping action and can be interpreted in a similar manner. Communicating transparently within the organisation leads to stakeholder support which is perceived essential to change an organisation and is an important criteria for a resilient strategy. Assumed is that this action contributes to an extension of the sell-by-date of action 1, 7, 8 with approximately 10 years.

Lobby for the applicability of new technologies is combined with action 8 and is related to the uncertainty of the speed of applicability of technology. When technology is not applicable, there is no need to implement the actions it is correlated with.

The action ‘collaborate with other ports’ might help to seize opportunities and hedge uncertainties of digitalisation and automation. Its potential is increased if it is combined ‘experimenting with new technologies’-action or with the ‘publish standards used by the PoR’-action.

A ‘reduction on the port-tariff’ has no direct impact on the long-term-objectives but is an action mitigating and hedging the uncertain adverse effects of inefficiency. This action therefore is not necessary to be implemented unless in the case this inefficiency occurs. In this way the action can contribute to an extension of any other action that might for some reason decrease efficiency in the port-call-process. For instance, the action ‘invest in big data analysis and algorithms’, might not contribute to efficiency or safety, since testing new software might lead to mistakes. However, after a period of testing, this action might increase efficiency. To mitigate the uncertainty of adverse effects of this action, a reduction of the port-tariff might be a good option. Assumed is that a reduction of the port-call-tariff will contribute to an extension with a maximum of roughly five years.

‘Set requirements for stakeholders’ is a action only to be implemented in the ‘rippling forward’ and ‘missing the boat’-scenario, with a weak collaboration between stakeholders. This means it cannot be combined with action number 10 and 11, which requires a collaboration with stakeholders.

The external collaboration actions help to reduce the uncertain effects of digitalisation and automation. They are only available in scenarios with a strong collaboration with stakeholders.

CURRENT PROJECTS

The link between current projects and programmes the Harbourmaster is working on is perceived as a relevant criteria to determine the sequence of actions. Due to an understanding of the idea of an action throughout the company, actions that fit in the current operations are more likely to be implemented than actions that are new and might be disruptive (Al-Ghamdi, 1998; Heide et al., 2002). In addition, current projects already fit in the vision of the Harbourmaster and thus are assumed to be desirable by the organisation to implement, which is an important element when designing a resilient strategy. The current initiatives of the Harbourmaster with respect to digitalisation and automation as elaborated upon in chapter 5, section 5.4, serve as reference and are visualised in bold in table 8.2

Based on all information of the sequence and sell-by-date of the strategies, the pathways for the resilient port-call-process roadmap can be designed. Just like in the DAPP design by Kwakkel and Haasnoot (2013), in this research the choice has been made to design the resilient strategy roadmap based on two scenarios. This leads to a roadmap that is relatively easy to read and still resilient since it takes into account multiple futures. Scenario 2 ‘all hands on deck’ and scenario 3 ‘rippling forward’ have been chosen to incorporate in the roadmap, since these are the considered the most extreme scenarios; an enormous potential of digitalisation and automation due to strong collaboration, but coming along with threats and uncertainties. On the other extend the ‘rippling forward’-scenario where development in the port is hard to accomplish with little improvements.

8.2. RESILIENT STRATEGY ROADMAP

The design of the roadmap is based upon the metro-map design of the Dynamic Adaptive Policy Pathways framework, as described in chapter 2, section 2.1.2. The basic roadmap is presented in figure 8.2.

The pathways are coloured based on the area of impact of digitalisation and automation. The sell-by-date, or adaption tipping point, is visualised with a black stripe on the end of some pathways. The circles represent a decision point at which the Harbourmaster can decide to transfer to a new action or stay on the same path. Vertical lines represent correlations between actions that may extend the sell-by-date of the action. Pathways that are not linked, can be implemented at any time in case other actions do not contribute to the long-term-objectives. The actions can be implemented in a sequence, meaning that previous actions are not discarded when moving to another strategy.

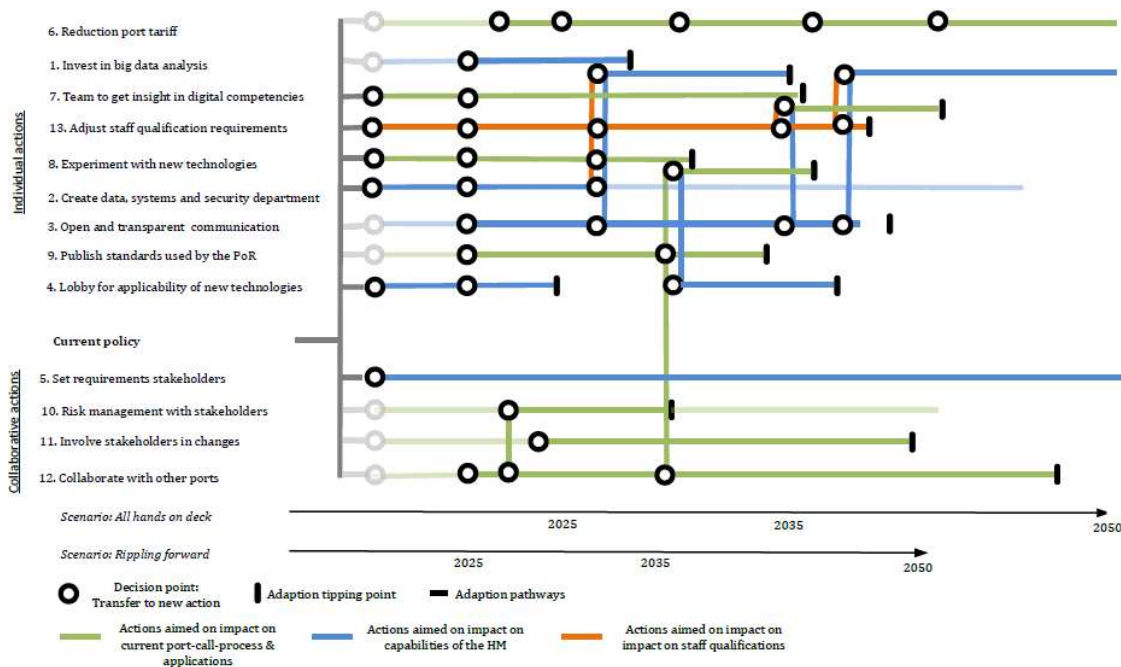


Figure 8.2: The resilient strategy roadmap

The Y-axis shows the developed actions. To construct the pathways, the actions are grouped into actions that can be executed by the Harbourmaster and do not require collaboration with other organisations (from the current policy to the top) and actions that involve other organisations in their execution (from the current policy to the bottom). Some pathways are partly visualised in a transparent colour. This indicates actions can start earlier or last longer, but it is not recommended based on the sell-by-date, the relevance or the assigned starting period during the workshop.

The X-axis represents the time in years until 2050. As has become clear, the scenarios with a rapid applicability of technology often have a sell-by-date different than the scenarios with a moderate applicability of technology. To incorporate the adaptability of a 'resilient strategy' in the roadmap, two timelines are visualised. This often results in an action with more than decision points to transfer to a different strategy.

The scenarios indicate the difference in time the decisions about the transfer should be made. For instance, for the first action, investing in big data analysis, depending on the scenario in which the Harbourmaster finds himself, he is obliged to make a decision either in 2022 (rippling forward) or in 2025 (all hands on deck). In case he chooses to execute the action, the sell-by-date of this action will be either be in 2028 for the 'all hands on deck'-scenario, or in 2033 for the 'rippling forward'-scenario. In case the Harbourmaster wants to continue with investing in big data analysis, he has to extend the sell-by-date by starting a different action. Following the orange line, will lead to the action 'adjust staff qualifications'. If the Harbourmaster transfers to this action, continuing with investing in big data analysis will contribute to the long-term-objectives until 2035 in the 'all hands on deck'-scenario and till 2040 in the 'rippling forward'-scenario. In case the environment changes, and the action does not contribute to the long-term-objectives anymore, the Harbourmaster might decide to switch to a different action to mitigate these effects.

8.3. PREFERRED PATHWAYS

Preferred pathways are pathways that fit well within a specified perspective. The original DAPP as designed by Kwakkel and Haasnoot, is designed for multiple stakeholders. According to Haasnoot et al., different decision makers and stakeholders can have different preferred pathways, depending on their values and beliefs (Haasnoot et al., 2013). Therefore it can be useful to specify two to four pathways that reflect different perspectives. This will result not only in the identification of physically robust pathways, but also 'socially robust' pathways (Offermans et al., 2011). The DAPP designed in this research is only meant for the Harbourmaster to use and to equip him with a tool to identify a resilient strategy to anticipate digitalisation and automation in the port-call-process. Yet, the Harbourmaster has different perspectives on his own role in the port-call-process. Therefore two preferred pathways are proposed.

The perspectives are based upon the vision of the Harbourmaster as identified in chapter 4 and the actions corresponding to the preferred scenario as specified in chapter 7, section 7.2.5. The vision of the Harbourmaster is to facilitate a smooth and safe port-call-process. This implies the Harbourmaster's role is a facilitator in the port-call-process. When external factors, such as weak collaboration, put pressure on the performance of the port-call-process, the Harbourmaster is forced to maintain safety and efficiency by controlling the port-call-process (Seignette, 2018). Therefore the pathways visualised in figure 8.3 represent the Harbourmaster as controller or the Harbourmaster as facilitator. The preferred scenarios are the scenarios with a strong collaboration between all stakeholders in the port-call-process. This means extra attention to the collaborative actions should be paid in the preferred pathways.

As is illustrated in figure 8.3, different perspectives on the role of the Harbourmaster result in different resilient strategies. For the controller perspective, actions such as publish standards and setting requirements for stakeholders are relevant in order to maintain a safe and efficient port-call-process.

For the facilitator perspective, the expectation is that all organisations cooperate and have interest in maintaining a safe and efficient port-call-process. The Harbourmaster's role is more passive and he is responsible for facilitating this collaboration of organisations so that the long-term-objectives are achieved. The stakeholder collaboration actions are important in this perspective.

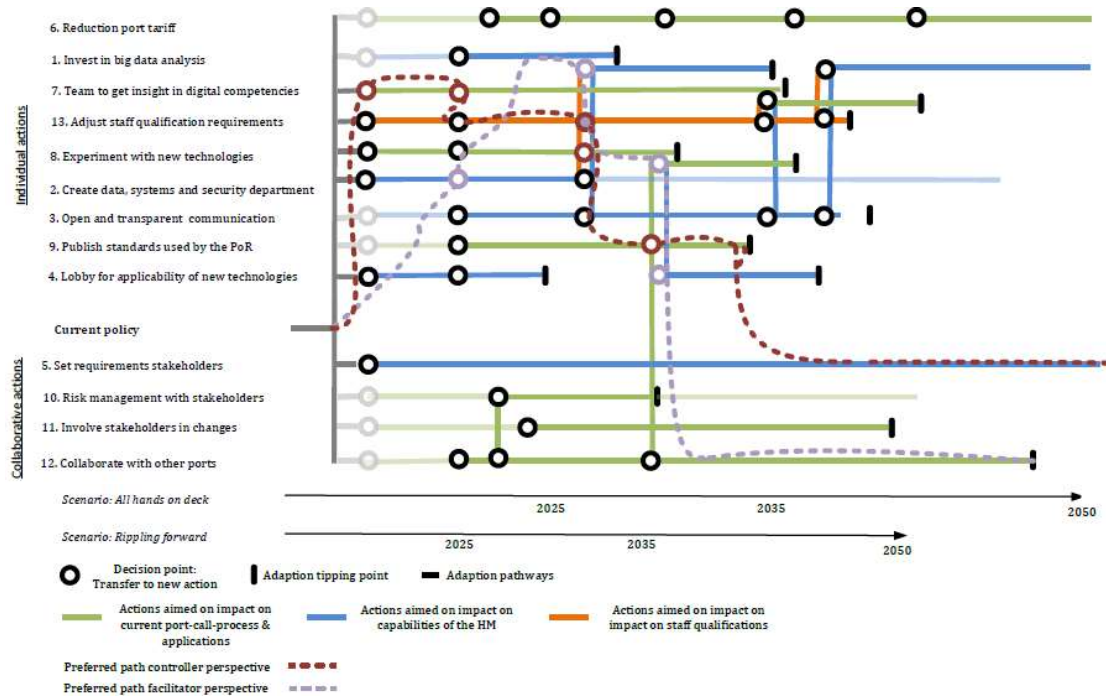


Figure 8.3: Resilient strategy roadmap with preferred pathways for two perspectives

In both perspectives, still a combination of the different actions aimed at the three areas of impact of digitalisation and automation is required to create a resilient strategy. The Harbourmaster should carefully choose which actions to implement at what time, and which actions might strengthen each other or mitigate and reduce the chance of failure of other actions.

8.4. CHAPTER SYNTHESIS | RESILIENT STRATEGY ROADMAP

By combining various elements concluded in previous chapter, an answer is provided to the last sub-question 'How does the strategy roadmap for the Harbourmaster look?'.

The traditional DAPP is a quantitative method for an organisation to adapt, grow and survive in face of change. In this research a qualitative approach is applied to design the adaption pathways. The sell-by-dates and sequence of the actions define the design of the pathways and are estimated based on information retrieved from literature and expert interviews. An essential element of the roadmap as is designed in this chapter, is the division between three types of actions. Organisational actions, process-related actions and one staff-related action all seizing opportunities or addressing problems in the three main areas of impact in the port-call-process. By distinguishing these types of actions, the actions are effective and help the Harbourmaster's organisation grow and survive in a changing environment. A resilient strategy should therefore contain at least one of each type of action.

The pathway map is used to illustrate potential connections between actions and where a sequence of two different actions can strengthen each other to contribute to a more resilient strategy. The roadmap is mapped out against the 'all hands on deck'-scenario and the 'rippling forward'-scenario since these represent two extremes. By means of decision points, the Harbourmaster knows when he has to choose to transfer to a different action. In addition, the roadmap shows when a sequence of action contributes to an extension of the sell-by-date of the actions and which actions strengthen each other.

Based on the roadmap, the Harbourmaster can choose his role and position in the port-call-process while being able to achieve the long-term-objectives. A resilient strategy in role of controller and the role of facilitator have been proposed, both contributing to reach the long-term-objectives.

IV

CONCLUSIONS

CONCLUSION AND DISCUSSION

This research focuses on designing resilient strategies for the Harbourmaster to anticipate to the impact of digitalisation and automation in the port-call-process. The Dynamic Adaptive Policy Pathway (DAPP) framework is applied to design a resilient strategy roadmap.

The main findings of this research are substantiated in section 9.1 by answering the sub-questions, followed by the final conclusions of this research in section 9.2. Next, the methodology and outcomes of this research are reflected upon in section 9.3. Finally, the findings of this research lead to recommendations which will be elaborated in section 9.4.

9.1. MAIN RESEARCH FINDINGS

The main research question answered in this study is ‘what are resilient strategies for the Harbourmaster to anticipate to digitalisation and automation of the port-call-process?’. To provide a structured answer to the main research question, six sub-questions are formulated, corresponding to the steps of the DAPP framework. First, the sub-questions are addressed followed by an answer to the main research question.

1. How is the port-call-process currently organised?

The port-call-process is ‘the processes and actions involved with the completion of vessel calls between the first notion of an arriving vessel and the last contact’. The port-call-process is divided in six sub-processes. These are organised by a strong collaboration and adequate information exchange between the organisations. This information is retrieved from the Automatic Identification System, radar and cameras and from (nautical) rules. Furthermore, tacit knowledge is an important basis for decision making among all organisations in the port-call-process.

The role of the Harbourmaster in this process is to manage vessel traffic by gathering all information and services provided by the organisations and reporting all relevant information to the vessel master and nautical service providers to maintain a smooth completion of vessel traffic.

2. What are the objectives of the Harbourmaster for the port-call-process?

The port-call-process is an overarching process involving many organisations that all have their own procedures and interests. Additionally, the port-call-process is influenced by regulations and societal norms (formal and informal institutions). The Harbourmaster has been made responsible for facilitating this process by the State and is obliged to report about the performance of the process. For these reasons, defining the objectives of the Harbourmaster is complicated.

Taking into account performance indicators that are reported to the State as well as the own vision of the Harbourmaster, results in the following two long-term-objectives that are used in this research: safety, in terms of number of accidents, and efficiency, defined by the total amount of time of delays.

3. How do the trends of digitalisation and automation affect the current port-call-process?

Digitalisation and automation affect all facets of the port-call-process, directly or indirectly. Where digitalisation is the transition of analogue data and tacit knowledge to digital information, automation is by means of digitalisation, acquire data and human tacit knowledge so that the system can replace (partially

to fully) human labour. These definitions result in the distinction of four levels of impact of digitalisation and automation; in the acquisition of information, the analysis of information, decision-support and decision-implementation.

At this moment, a significant part of the port-call-process is analogue (e.g. Very High Frequency, tacit knowledge, clearances) and is directly affected by digitalisation and automation. An indirect impact can be found in three areas:

1. The impact on the capabilities of the Harbourmaster's organisation with respect to the long-term-objectives of the port-call-process,
2. The impact on the current port-call-process and the applications,
3. The impact on staff qualifications required to support the port-call-process.

However, the specific impact, including both opportunities and threats, is uncertain and depends on the level of impact and the speed with which digital applications can be implemented. In addition, collaboration between organisations is an uncertain factor with consequences for the amount of data that can be digitalised and/or automated.

4. How can future scenarios contribute to a resilient strategy for the Harbourmaster in order to anticipate to digitalisation and automation in the port-call-process?

A resilient strategy allows the Harbourmaster to survive, adapt and grow in face of change. To cover a wide range of changing environments, four scenarios are designed based on the most critical uncertainties with respect to digitalisation and automation. These are the level of cooperation between the organisations in the port-call-process (weak or strong) and the speed at which the developments in technology are applicable (moderate or rapidly).

Based on the impact of digitalisation and automation, the scenarios evoke challenging questions, threats and opportunities on all aspects of the port-call-process. By generating a better understanding of the risks involved with changes in current operations that come along with uncertainties, scenarios contribute to a resilient strategy. Based on the scenarios, the Harbourmaster can position himself and generate action plans to respond to their eventualities. A resilient strategy can be developed based on these actions to respond to a wide range of opportunities and threats in multiple scenarios.

5. What are effective actions the Harbourmaster can undertake to anticipate on the impact of the scenarios?

Effective actions address or avoid problems or seize opportunities in the areas of impact of digitalisation and automation in the port-call-process. Most problems are identified in the area related to the organisation of the Harbourmaster. This might imply a lack of agility to anticipate to changes in his environment.

An amount of conceptual actions is identified that seize opportunities or address problems. Aggregation and specification of the conceptual actions, resulted in a list of thirteen examples of concrete actions as is listed in table 9.1. The classification of the action correspond their impact on uncertainties (mitigate negative effects, hedging uncertain effects, seize opportunities) or their relation with other actions (shaping actions reduce the chance of failure of other actions).

Table 9.1: Effective actions to be used in the roadmap

Concrete action	Classification
1. Invest in big data analysis and algorithms	Seizing, hedging
2. Create 'data, systems and security'- department	Seizing, hedging
3. Communicate open and transparent	Shaping
4. Lobby for applicability of new technologies	Shaping
5. Set requirements for stakeholders	Mitigating, hedging
6. Reduction of port-tariff	Mitigating, hedging
7. Get insight in digital competencies	Seizing
8. Experiment with new technologies	Seizing
9. Publish standards used by the Port of Rotterdam	Mitigating

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Concrete action	Classification
10. Risk management with stakeholders	Mitigating, hedging
11. Involve stakeholders in changes	Seizing, hedging
12. Collaborate with other ports	Seizing, hedging
13. Adjust staff qualifications	Mitigating, shaping

As some actions directly affect the objectives of the port-call-process, other actions focus on the impact of digitalisation and automation on the organisation of the Harbourmaster and the required staff qualifications. The latter ones mitigate uncertainties and reduce the chance of failure of other actions. The list of actions, the distinction between three types of actions and their classification is used in the resilient strategy roadmap.

6. How does the strategy roadmap for the Harbourmaster look?

A qualitative method is applied to assemble the pathways for the resilient strategy roadmap. The actions as listed in table 9.1 are used and their sell-by-date and sequence is assessed based upon literature review, expert interviews and the results from the brainstorm-workshop.

The roadmap is based upon the DAPP framework as designed by Kwakkel and Haasnoot. To be able to address potential problems and to seize opportunities of digitalisation and automation, a resilient strategy should contain at least one of each type of action (organisational action, process related action and the staff related action). This implies that no matter what scenario the Harbourmaster finds himself in, he should adjust the staff qualification requirements in order to address problems that digitalisation and automation might bring in this area.

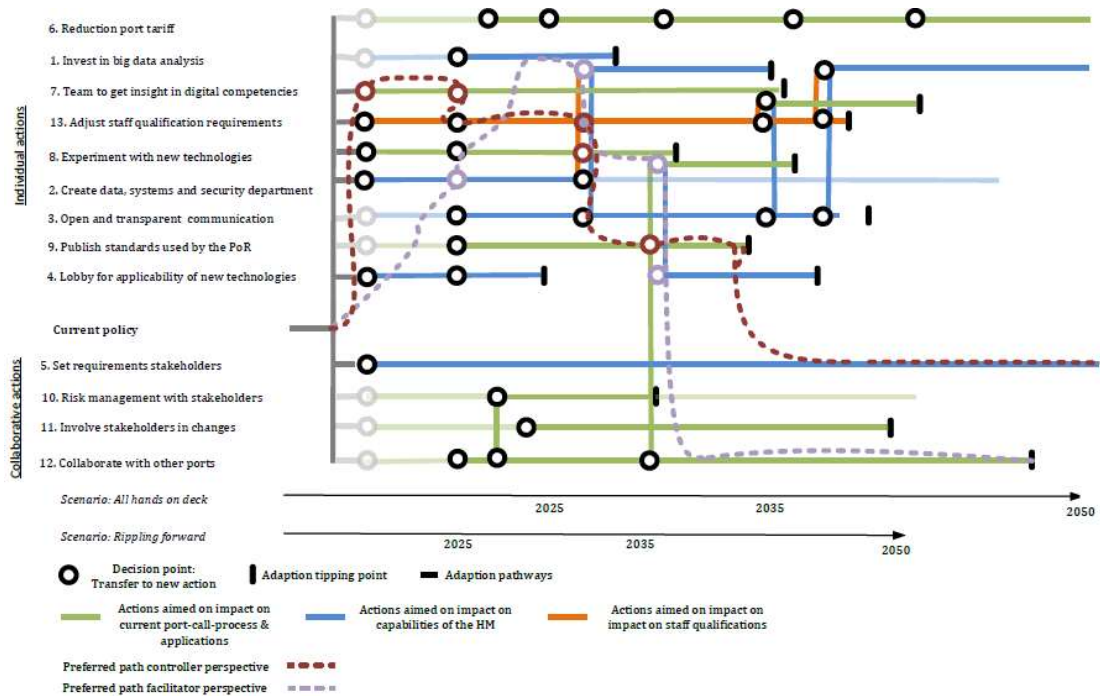


Figure 9.1: The resilient strategy roadmap

Figure 9.1 represents the resilient strategy roadmap. Potential connections are illustrated by a vertical line and show where a sequence of different actions can strengthen each other or extend the sell-by-date of a different action. In order to guarantee for resilient, actions are mapped out against two extreme possible futures. The 'all hands on deck'-scenario including a strong collaboration and rapid applicability of technology and the 'rippling forward'-scenario, including weak collaboration and moderate applicability of technology. Decision points, based on the sequence and sell-by-date, differ per scenario. They provide an indication whether

the Harbourmaster should transfer to a different action. Whenever an action is not contributing to a safe or efficient port-call-process, the Harbourmaster should implement another action as supplement to or substitute of the previous action. Due to the qualitative assembling of pathways, one of the main contributions of this roadmap is the visibility of the relevance of actions. There is found that actions concerning technology and organisational change have an adaption tipping point sooner and thus are more relevant in the 'all hands on deck' scenario than in the 'rippling forward' scenario.

Based on this roadmap, the Harbourmaster can position himself in the port-call-process while contributing to achieve the long-term-objectives. He can choose his role by implementing actions that imply a controlling role, such as publish standards used by the Port of Rotterdam, or set requirements for stakeholders. A facilitating role is possible and more suitable in a scenario with a strong collaboration of organisations. An example of a resilient strategy from different perspectives is illustrated by the dotted lines in figure 9.1.

9.2. CONCLUSIONS

This research has been carried out to help the Harbourmaster to respond and anticipate to the impact of digitalisation and automation in the port-call-process. From literature study no specific methodology was found to design a resilient strategy for such purposes in a structured way. To fulfil the aim, this research provides a structured approach to identify the impact of digitalisation and automation in the port-call-process as well as a qualitative approach of the DAPP framework to develop a resilient strategy roadmap. It thereby answers the main research question: *What are resilient strategies for the Harbourmaster to anticipate to the impact of digitalisation and automation in the port-call-process?* By answering this main question, there can be concluded that the qualitative application of the DAPP in this research therefore is a suitable method to develop resilient strategies.

The following list shows the characteristics of a resilient strategy and elaborates how the qualitative application in the adjusted DAPP (see chapter 2) in this research satisfies these criteria. A resilient strategy:

1. Helps the Harbourmaster to survive, adapt and grow in face of change due to the uncertain impact of digitalisation and automation.
In the first three steps, threats and opportunities of digitalisation and automation are defined in four different scenarios. A list of examples of concrete and effective actions is developed based on these threats and opportunities.
2. Guides decision-making towards the long-term-objectives of safety and efficiency in the port-call-process.
With the inclusion of a feedback loop, the designed actions are assessed based on their contribution to a safe and efficient port-call-process. Actions that did not contribute are not included in the final resilient strategy roadmap.
3. Is desirable by the organisation to implement.
Pathways in the resilient strategy roadmap are assembled qualitatively, based on their relevance and their relation to current projects. In addition, employees from the Harbourmasters organisation are included in the design of strategies and the selection of preferred scenarios.

It has been found that there is not 'only one' resilient strategy for the Harbourmaster to anticipate to the impact of digitalisation and automation. An important note therefore is that the resilient strategy roadmap should be interpreted as a guideline and not as a strict set of actions. The contribution lies in the identification of the areas of impact of the actions with respect to the areas of impact of digitalisation and automation in the port-call-process. The Harbourmaster can use the description of actions and their correlations to identify actions that strengthen each other or mitigate uncertainties. Different combinations of actions result in different resilient strategies. However, it has been found that each combination of actions should include at least one of each type of actions to cover all areas of impact of digitalisation and automation.

Additionally, there are three main problems found during the brainstorm-workshop, interviews and when analysing future scenarios that should be taken into account in strategic decision-making. Firstly, the conversion of tacit knowledge to digital data, while maintaining the ability to understand the systems and process to avoid IT dependence. Secondly, digitalisation and automation are expected to cause problems in the harmonisation and security of processes and systems of organisations in the port-call-process, which might

result in efficiency decrease. Thirdly, the introduction of autonomous vessels in the port-call-process will be challenging, especially in the transition phase where traditional vessels and autonomous vessels interact. Problems related with safety and efficiency are expected, but also a different role of the Harbourmaster might be required. Recommendations related with amongst others these problems are presented in section 9.4.

9.3. DISCUSSION

This research provides a method to develop resilient strategies in an uncertain, complex environment. This method is applied to the case of the Harbourmaster's department: digitalisation and automation in the port-call-process. The final resilient strategy roadmap as well as the steps taken to achieve this result are assumed to be complementary to the current literature and methodologies. It is therefore suggested that other cases need to consider the use of the methodology, when digitalisation and automation are expected to change the current processes of an organisation.

The resulting resilient strategy roadmap shows similarities but at the same time also has a different purpose than the traditional DAPP roadmap. On the one hand, the strength of the DAPP method can be found in the resilient strategy roadmap since it stimulates the policy makers, such as the Harbourmaster, to include adaption plans in their planning, to keep the system headed towards the original goals (Haasnoot et al., 2013). On the other hand, the qualitative approach in this research, lets the roadmap serve as a tool to compare types of actions based on their qualitative impact and classification and to discover possible combination of actions that strengthen each other. The strategic objective and lack of quantitative data, results in a clear difference compared to the DAPP in the traditional format, where the intention is to determine how long decisions can be postponed. Therefore, in the resilient strategy roadmap the sequence of actions is leading compared to the original DAPP framework where the time component is essential.

There can be discussed whether a qualitative approach is sufficient to develop resilient strategies for other organisations. This might depend on the objectives, role and perspectives of the organisation. For policy makers, dealing with long-term objectives and operating in a slowly changing environment, a qualitative approach is assumed to be sufficient. Planners in more operational organisations or departments might prefer to know the exact quantitative impact of uncertainties and actions on short term. If necessary, a quantitative method to design scenarios, including threats and opportunities as well as generation of actions and establishment of sell-by-dates, can then serve as a supplement. In this case, to determine the success of actions and pathways, quantitative long-term-objectives are essential (Haasnoot et al., 2013).

Another matter for debate is the inclusion or exclusion of contingency planning (planning of additional actions in case the current actions do not contribute to the long-term-objectives). The adjusted DAPP framework used in this research to design resilient strategies, does not include contingency actions, which is opposite to the traditional DAPP. Since the resilient strategy roadmap satisfies all criteria relevant for a resilient strategy (see section 9.2) this is not perceived necessary. In addition, during the brainstorm-workshop, experienced strategists of the Port of Rotterdam assessed the developed actions based on their contribution to safety and efficiency. Therefore the identified actions are perceived to be effective. On the other hand, the lack of familiarity of the participants with the DAPP approach could be a reason to include contingency planning, to guarantee for resilience. In addition, contingency planning might be useful in case the participants in a brainstorm session are not experienced in the field.

As for the identification of areas of impact, it is expected that that for other organisations that follow the steps as presented in this research, similar areas of impact will be identified. This results in the understanding that in order to avoid threats that come along with digitalisation and automation of the processes, actions only can succeed if the organisation and staff qualification changes as well. However, the content of the process-related actions will differ due to different, case dependent, uncertainties and elements in the process.

9.4. RECOMMENDATIONS

This research is built on several assumptions and simplifications that may lead to imperfect results. The scientific limitation of this study is discussed in the following section as an opportunity to conduct further research. However, this does not refute the fact that some important insights can still be inferred as learning points for practice. This is elaborated in section 9.4.2.

9.4.1. RECOMMENDATIONS FOR FURTHER RESEARCH

The recommendations to be considered when this research will be performed again or when the methodology will be applied to other cases are discussed in this section. In addition, important findings concerning the content of the research that are recommended to investigate in another research are elaborated.

RECOMMENDATIONS RELATED TO THE METHODOLOGIES

Eight interviews were held with experts from the Harbourmaster's department as well as external experts. Even though this resulted in a wide range of information retrieved from different perspectives, it is recommended for other researchers to include all stakeholders in the set of experts, since this may improve and extend the knowledge base for the research.

Critical uncertainties defining the scenario-logic are now identified by means of logic reasoning and literature. Although the scenarios in this research have been verified by experts from different departments, it is recommended to establish scenarios in a group setting rather than on individual basis. When managers get more involved with scenarios, the more likely it becomes that they will recognise the importance of resilient strategies to anticipate to these futures, which might result in an increase in organisational support. In addition, this might have led to different driving forces and deep uncertainties, which results in different scenarios and therefore different types of actions to be implemented.

The involvement of experts in the development of actions by means of a brainstorm workshop contributed to creativity and effective actions to act upon a wide range of threats and opportunities in various scenarios. However, only four employees participated in the brainstorm-workshop. These participants all stemmed from strategic departments of the Harbourmaster resulting in a lack of operational actions. In addition, the duration of the workshop was 2.5 hours, which was rather short. By organising a brainstorm-workshop that lasts longer, including more participants from different departments or even other organisations, a larger amount of diverse actions could have been retrieved. For future researches including a brainstorm-workshop, it is recommended to reserve more time and to include a higher amount of participants stemming from different organisations, to achieve a wider set of more valid actions and to realise consistency among all actions in the scenarios.

The last recommendation reflects on the assembling of the pathways. Pathways can be assembled in various manners. In this research, the pathways were established qualitatively, based on the sell-by-dates, taking into account the contribution towards long-term-objectives and their relevance, and based on the sequence of actions, taking into account the current initiatives, the starting period and the correlation of actions. Different research might require different aspects to be taken into account, such as risks associated with the actions, costs of the actions or availability of resources. When a different research applies the DAPP in a qualitative manner, it is recommended to investigate what factors are most suitable to use in that case, since this influences the sequence and sell-by-dates of actions.

RECOMMENDATIONS RELATED TO RESEARCH FINDINGS

The most extended level of automation in the port-call-process is automatic implementation of actions. One of the major developments that is expected to have a radical impact on maritime operations is the introduction of autonomous vessels (AV's) (Cappelle, 2017; Chong, 2018; SmartPort, 2018). Even though autonomous vessels are mentioned as a disruptive factor in the scenarios, no problems were identified on this field during the brainstorm-workshop with experts from the Port of Rotterdam. This might be the reason of the selection of candidates for the workshop. Only strategists attended the workshop, who believe autonomous vessels will only be introduced if there are no threats or risks involved, and therefore did not perceive the introduction of AV's as a problem. The result is that the resilient strategy roadmap does not include actions aimed at facilitating the introduction of autonomous vessels. From the interviews and literature study, there is no doubt that (variants of) autonomous vessels will be introduced within thirty years from now (Cappelle, 2017; Negenborn, 2018; Smartport, 2018). Major consequences are expected in the transition phase where autonomous vessels interact with conventional vessels (Chong, 2018). Therefore it is strongly suggested to investigate this aspect further, and at least including; the impact of the introduction of autonomous vessels on safety, the opportunities of autonomous vessels for efficiency, the expected change in tasks of the organisations in the port-call-process and the need for adjustments in (IT)-infrastructure.

From interviews as well as literature has been learned that great improvements are to be made in the field of planning of vessels (arriving and departing) and of the Nautical Service Providers. The terminals turned out to play an essential role in distributing accurate information about availability of berths. This research's main focus is on the period between the first contact of the vessel to the moment of berth, meaning all processes that happen after berth that have influence on the planning were not taken into account. Since this turned out to be an important aspect of the planning of vessels, opportunities lie among others in the fields of synchromodal transport and Just-In-Time transport. Recommended is to conduct further research to the opportunities of digitalisation and automation concerning the planning of terminals.

9.4.2. MANAGERIAL RECOMMENDATIONS

When answering the sub-questions of this research, a deep dive into the Harbourmaster's operations was required. This led to several observations from literature, interviews and the methods used to answer the questions. Recommendations based on these observations for the Harbourmaster are as follows:

ESTABLISHMENT OF CONCRETE PERFORMANCE INDICATORS

The current KPIs the Harbourmaster measures and reports are influenced by the performance of many other organisations. The Harbourmaster is therefore not responsible for the improvement or deterioration of the indicators. When implementing new or evaluating existing policies and to be able to measure effects of certain trends, such as digitalisation and automation, it is recommended to establish concrete, measurable performance indicators with a responsible stakeholder or department to measure if new actions or policies have the desired effect (Haasnoot et al., 2013). An example is an indicator such as 'duration of clearance checks' with the Harbourmaster's department as responsible stakeholder.

COLLABORATION WITH OTHER ORGANISATIONS

During interviews and the brainstorm-workshop, collaboration with organisations in the port-call-process, but also external organisations and other departments in the Port of Rotterdam was perceived as essential to seize opportunities of digitalisation and automation.

Collaboration between other organisations in the port-call-process was perceived as a crucial element for the well-performing of the port-call-process. Therefore it is recommended to focus on actions that require collaboration between organisations to increase the resilience of the strategy and to improve efficiency in the port-call-process. In addition, to stimulate the development and applicability of new technologies in the Port of Rotterdam, the Harbourmaster should invest in collaboration with knowledge institutes (Negenborn, 2018; Tabak, 2019).

Not only external organisations should be involved in the possible changes in the port-call-process. In order to seize opportunities and to avoid threats, other departments of the Port of Rotterdam should be included as well. A concrete example is the installation of sensors in quay walls which is beneficial for the Harbourmaster and asset management department. Sensors can be used to measure occupancy to support a more accurate planning of vessels which improves efficiency and on the same time these sensors could help in providing information about the status of the quay wall relevant for maintenance.

IMPORTANCE OF TACIT KNOWLEDGE

Tacit knowledge is an important source of information in all sub-processes in the port-call-process. Next to the fact that this type of information is difficult to digitalise, it is not always desirable. Several experts as well as sources in literature mention the importance of tacit knowledge in the maritime sector and the risk of IT dependence, especially in case a computer or system fails or breaks down (Chong, 2018; Newell & Marabelli, 2015). It is recommended for the Harbourmaster as well as for other organisation where tacit knowledge is an essential source of information, to carefully choose which types of information opt for digitalisation and to be aware of the importance of human power to understand current processes.

ALIGNMENT WITH THE HARBOURMASTER NEXT GENERATION PROGRAMME

The main findings of this research as well as the previously mentioned managerial recommendations, fit best in the Harbourmaster Next Generation programme (HMNG) at the Harbourmaster's department (see chapter 5). Recommended for this programme is to use the scenarios developed in this research as a starting point to raise awareness with respect to the impact of digitalisation and automation on the current processes as well as a tool to effectively implement new actions. The three main problems that are expected based on these

scenarios could be used as a guideline. In addition, the developed examples of actions, could be taken into account and be detailed further in the current set up of the HMNG programme.

Currently, the HMNG programme consists of four main pillars that all focus on seizing opportunities of digitalisation and automation in the various sub-processes of port-call-process. Expected problems are not examined and the programme therefore does not adapt to the changes these problems might cause. Tangible suggestions for action plans are as follows and based on the three main problems that are expected and discussed in the recommendations. In changes in processes and IT systems in all four pillars experienced employees should be included to prevent tacit knowledge from being lost and there should be paid attention on the transfer of knowledge to new employees. In addition, since all pillars include processes with other organisations, it is recommended to include these organisations in (e.g. monthly) meetings to adjust processes and systems and to maintain support for changes. The final recommendation to be implemented in the HMNG programme which mainly fits in the ‘traffic management’-pillar, is the inclusion of the interaction of autonomous and traditional vessels, and the respond to problems this might cause.

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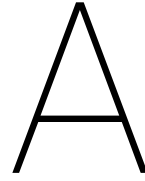
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V

APPENDIX



SCIENTIFIC PAPER

This research is executed in fulfilment of the requirements for the degree of Master of Science in Transport, Infrastructure and Logistics. As an extra requirement to obtain the Master's degree and to increase the impact of this research, a scientific paper is written which lays emphasis on the scientific contribution of this research.

A resilient strategy roadmap for the Harbourmaster in an uncertain environment of the port-call-process

A QUALITATIVE APPLICATION OF THE DYNAMIC ADAPTIVE POLICY PATHWAYS FRAMEWORK

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Abstract—With the upsurge of disruptive trends such as digitalisation and automation, organisations have become more vulnerable to the consequences of these disruptive trends. The Harbourmaster is responsible for facilitating a safe and efficient port-call-process. Digitalisation and automation might lead to opportunities and threats in the port-call-process the Harbourmaster cannot for see. As a result, the need for more resilient strategies to respond to these trends has become paramount. This research aims on filling the gaps in literature, by developing a strategy roadmap for the Harbourmaster to manage uncertainties in the port-call-process due to digitalisation and automation. By doing so, it provides a structured approach to examine the impact of digitalisation and automation in the port-call-process. Digitalisation and automation affect the capabilities of the Harbourmaster's organisation with respect to long-term-objectives, the impact on the current port-call-process and the applications and the impact on staff qualifications. Adjustments to the Dynamic Adaptive Policy Pathways framework have been made to fit it into the objectives of this qualitative research. Resulting in thirteen effective actions that contribute to long-term-objectives to respond to the uncertainties (both opportunities and threats) of digitalisation and automation in different futures of the port-call-process. All actions focus one of the areas affected by digitalisation and automation. The resilient strategy roadmap visualises correlations between the actions. Concluded is that a qualitative application of the DAPP can be used to design resilient strategies for the Harbourmaster. The resilient strategy roadmap provides the Harbourmaster with a guideline that is useful in uncertain environments due to digitalisation and automation. It can be discussed if other cases would experience the similar results when applying the DAPP framework in a qualitative manner. Furthermore, different set-up of methodologies is expected to result in a more valid set of actions. In addition, the impact of autonomous vessels is recommended to be further investigated since this is expected to have a radical impact on the port-call-process.

Keywords—automation, digitalisation, DAPP, decision-making, port-call-process, resilience, scenario-analysis, strategy, uncertainty

I. INTRODUCTION

The Port of Rotterdam (PoR) is the twelfth largest port in the world and the largest port of Europe in terms of cargo tonnage and container traffic (IAPH, 2017; Notteboom, 2015).

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Furthermore, in terms of port planning and port development, the PoR is globally considered as a leading port (Notteboom, 2015). For shipping companies, the optimum deployment of their fleet plays a key role in their selection of a specific port (Port of Rotterdam, 2014). This optimum depends on the level of efficiency of a port. High quality port operations contribute to the competitive advantage by reducing the port time for vessels (Moon & Woo, 2014).

Considering the Port's complex planning processes with many organisations, efficiency lies in managing all processes and actions involved with the completion of vessels. The Harbourmaster is responsible for facilitating a safe and efficient completion of vessels in the Port of Rotterdam.

New disruptive ICT innovations such as digitalisation and automation, come along with opportunities that might improve efficiency in port operations. On the other hand, they lead to unexpected changes and threats that are not identified for the Harbourmaster yet and might cause a decrease in efficiency and safety in the port-call-process. As a result, the need for strategies to respond to these uncertainties has become paramount.

A. LITERATURE GAP

Managing risks of an uncertain future is a challenge that requires resilience. A variety of approaches for supporting decision-making under uncertainties. The Dynamic Adaptive Policy Pathway (DAPP) framework seems a promising method to develop strategies to adapt to changes in a variety of uncertain futures (Haasnoot, Kwakkel, Walker, & ter Maat, 2013; Kwakkel, Walker, & Marchau, 2010a). However, it has only been designed to deal with impacts of climate change. The strategy aimed for in this research should help the Harbourmaster's organisation adapt, grow and survive in face of changes in the port-call-process due to digitalisation and automation, while guiding decision-making towards the long-term-objectives. In addition, this strategy should be desirable by the Harbourmaster's organisation to implement. Therefore this research aims to fill this gap in literature by developing a strategy roadmap for the Harbourmaster to manage uncertainties in the port-call-process due to changes in the environment.

Digitalisation and automation is becoming widespread in many organisations all over the world. Ports are facing this trend as well and must define a strategy to react to this

trend. Furthermore, an effective strategy should attack areas of impact of the trend. To the best of the author's knowledge, no attention has been given in literature to the assess the impact of digitalisation and automation in the port-call-process. The potentials of some of the applications of digitalisation and automation with respect part of processes of organisations is described. In the maritime sector, this comes down to implications of the trend for the entire supply chain or the introduction of autonomous vessels on parts of the port-call-process (Cappelle, 2017; Chong, 2018; Department for Transport, 2019; Gardeitchik, Buck, & Deijl, 2019; Schiaretto & Chen, 2017). However, a structured approach to investigate the areas of impact of the combination of digitalisation and automation in an organisation or processes of organisations is lacking. This research therefore aims to alleviate on this gap in research by providing a structured approach to examine the impact of digitalisation and automation in the port-call-process.

B. RESEARCH OBJECTIVES

This research is carried out to fill the knowledge gaps on the developments of a structured approach to identify the impact of digitalisation and automation in the port-call-process. To cover the first gap in literature, this research uses the DAPP framework as a cornerstone for the development of resilient strategies for the Harbourmaster in a changing environment. To do so, this research firstly aims to conceptualise the current port-call-process, the elements, the objectives as well as the trend of digitalisation and automation. Secondly, uncertainties that come along with this trend have to be examined in order for the Harbourmaster to understand scenario's that might affect their business. Finally, a concrete roadmap with resilient strategies will be developed to act upon the scenarios to give a full profile of the options the Harbourmaster has to manage the port-call-process. Subsequent, the following research question is formulated:

What are resilient strategies for the Harbourmaster to anticipate to the impact of digitalisation and automation of the port-call-process?

In this research, all processes and actions are described for inbound vessels. Therefore port-call-process is defined as the processes and actions involved with the completion of vessels between the first notice of arrival and the moment of berth. However, the designed strategies can also be applied for outbound vessels.

This paper is structured as follows. First, the methodology is outlined which describes how the results of this research are obtained, which is a case study at the Harbourmaster's department. In section IV, the results of this study at the Harbourmaster's department are discussed, as well as the scientific results of the use of the DAPP approach to design resilient strategies. The last section, section V, provides the concluding remarks.

II. RESEARCH METHODS

In this section the theoretical foundation for this research is discussed. This research is conducted as a case study at the Harbourmaster's Department in the Port of Rotterdam to test the applicability of the DAPP-framework to design resilient strategies. First the theoretical framework used in this case study is discussed. Furthermore, this section elaborates on the case study approach and the methods used in this case study to achieve the results.

A. THE DAPP FRAMEWORK

According to Haasnoot, 'decision makers facing a highly uncertain future need more than traditional prediction or scenario-based decision methods to help them to evaluate alternatives and make decisions' (Haasnoot et al., 2013). Dynamic adaptive plans are needed to develop plans in deep uncertain environments (Haasnoot et al., 2013; Kwakkel, Haasnoot, M., & W.E., 2016). A pathway roadmap can be used to illustrate the sequence of action plans to be taken (Phaal & Muller, 2009).

The DAPP framework combines the strengths of two bodies of literature on adaptive planning under uncertainty: Adaption Pathways (AP) and Adaptive Policy Making (APM) (Haasnoot et al., 2013; Kwakkel, Walker, & Marchau, 2010b; Walker, Haasnoot, & Kwakkel, 2013).



Fig. 1: Dynamic Adaptive Policy Pathway framework (Haasnoot et al., 2013)

The DAPP approach (see figure 1) starts with a description of the system and the identification of objectives and uncertainties that are relevant for decision-making. The uncertainties are then used to develop plausible futures by means of transient scenarios. These scenarios are compared with the objectives to see if problems arise or opportunities occur. Based on the problems and opportunities, actions are identified. These actions are assessed on their contribution to long-term goals and objectives and can be classified in four types: mitigating actions are actions to reduce the likely adverse effects of a

plan; hedging actions ought to spread or reduce the uncertain adverse effects of a plan; seizing actions to seize likely available opportunities and shaping actions are taken to reduce failure or enhance success (Haasnoot et al., 2013; Walker et al., 2013). This leads to adaption tipping points. An adaption tipping point, specifies the conditions under which a policy action will fail. It is reached when the effect of external changes is such that a policy no longer meets or contributes to its objectives. After this 'sell-by-date', additional actions are needed. The assessment of the distribution of the timing of adaption tipping points is typically derived from model simulations over transient scenarios (Haasnoot et al., 2013; Kwakkel et al., 2016). Promising actions are used as the basic building blocks for the assembly of potential adaption pathways, which is a sequence of actions over time to achieve the objectives under uncertain conditions. This can be presented in an adaption pathways map. The parameters retrieved from simulations can be used in a scorecard that helps in identifying the preferred pathways.

B. A CASE STUDY

The DAPP approach is used to design resilient strategies for the Harbourmaster. Since this approach has not been applied to guide decision-making for a specific organisation in the context of digitalisation and automation, it is tested by means of a case study at the Harbourmaster's Department. The main objective of case studies is to expand theories (analytic generalisation) and not to enumerate frequencies (statistical generalisation). Figure 2 shows the use of the case study in this research. The DAPP-framework serves as a template with which to compare the empirical results of the case study where these results lead to a broader theory (Yin, 2014). The light grey box contains

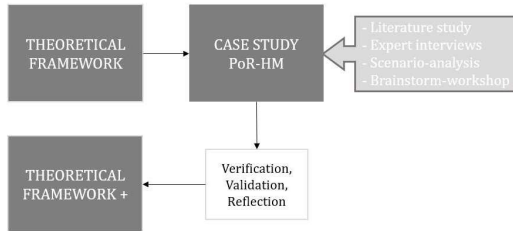


Fig. 2: Case study research design used in this research

all methods that are used to obtain the information required in this case-study. Four methods have been applied: Literature study, expert interviews, scenario analysis and a brainstorm-workshop. Both the literature study as well as expert interviews were used to gain more information about the port-call-process and digitalisation and automation. In total nine expert interviews were held with experts within the Harbourmaster's division as well as external parties.

The interviews led to an in-depth analysis of the system and its requirements. The literature review together with expert interviews served as input for the scenario analysis. The development of scenario's is done according to the steps of Schwartz

and leads to a description of four scenario's of the port-call-process with respect to digitalisation and automation. To improve the validity and reliability of this case study research, a brainstorm workshop is organised to identify potential usable actions in multiple scenarios to prepare for threats and to seize opportunities. By involving employees of the Harbourmaster's organisation in this workshop actions are developed that fit in the Harbourmaster's processes. These actions served as input for the final resilient strategy roadmap that can be used to identify a resilient strategy for the Harbourmaster to anticipate to uncertainties in the port-call-process in a changing environment due to digitalisation and automation. The final reflection reviews the use of the DAPP to design resilient strategies. Adjustments and improvements might contribute to an expansion of the DAPP-framework (Theoretical Framework+).

III. APPLICATION

The case study method is used to test if the DAPP framework can be applied to design resilient strategies for the Harbourmaster in the port-call-process in an uncertain environment due to digitalisation and automation. A resilient strategy in this research is defined as 'a strategy helping the organisation to survive, adapt and grow in face of changes in its environment, while guiding decision making towards long-term-goals'. Characteristics of a resilient strategy are as follows:

- helps an organisation to survive, adapt and grow in face of change due to societal developments and trends with an uncertain impact. In this report the main trend analysed is digitalisation and automation in the port-call-process.
- guides decision making towards long term goals.
- is desirable by the organisation to implement.

To design a resilient strategy, the DAPP framework was adjusted to fit in this research. Figure 3 shows the adjusted DAPP framework. This section discusses the adjustments made and their application in the case study.

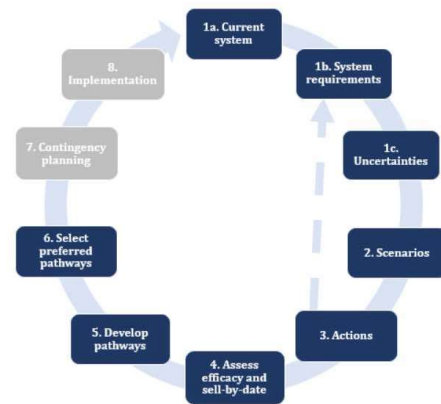


Fig. 3: Adjusted DAPP framework used in this research

- 1) The first step is to conceptualise the current system.
 - a) First the port-call-process is described. This includes all organisations involved in the port-call and the information (infrastructure) supporting this process.
 - b) Next the long-term-objectives and Key Performance Indicators of the Harbourmaster with respect to the port-call-process are identified. Together these form the system requirements.
 - c) The third step includes a specification and impact assessment of the major uncertainty that is expected to play a role in decision-making for the Harbourmaster: digitalisation and automation. This step is an essential step in order to fill the second gap in literature. The definitions of and interaction between digitalisation and automation are described and their potential in the current port-call-process is visualised in the processmap.
- 2) In the second step, scenarios are established. The specified objectives of step 1b are compared to the possible future situations to identify potential gaps. The major uncertainty identified in step 1c; digitalisation and automation, plays a different role based on the scenario. Both opportunities and threats are considered. Opportunities are developments that can help in achieving the objectives of the Harbourmaster, while threats are developments that can harm the extent to which the objectives can be achieved. Haasnoot et al. identify opportunities and threats based on the analysis of reference cases, which is accomplished by using a computational model. In this research the threats and opportunities of digitalisation and automation in an uncertain future are a qualitative interpretation and identified based on the description of the scenarios and complemented by perspectives of employees of the Harbourmaster's division.
- 3) In the third step, via a brainstorm-workshop with employees from the Port of Rotterdam, actions are identified to act upon the threats and opportunities identified in step 2. The realisation of this step is important for the design of a resilient strategy. To fit the final strategy in the Harbourmaster processes, the organisation should be involved in the development of strategies. By means of a workshop at the Harbourmaster's department employees will have the chance to brainstorm about problems, opportunities and relevant actions to deal with uncertainties. In addition, attention is paid to identify the preferred actions and the preferred scenario within the organisation to satisfy the third criteria of a resilient strategy. To assess the identified actions based on the long-term objectives of the Harbourmaster, a feedback-loop is included. The actions are assessed based on the long-term-objectives and aggregated to concrete actions usable for the next steps. The actions can be categorised according to the four types of actions (i.e. mitigating, hedging, seizing and shaping actions). The aim of this step is to assemble

a rich set of possible actions.

- 4) In the fourth step the sequence and the sell-by-dates of all strategies is determined. The sequence is based on the current operations of the Harbourmaster, the starting period and the correlation with other actions. The sell-by-date is based on the contribution to the long-term-objectives and the incubation period of the actions. All information needed to establish a pathway roadmap now is available. Originally, the DAPP is a quantitative approach. In this case study the adaption tipping points and actions will be assessed in a qualitative manner based on the perspectives and preferences from experts from the Harbourmaster's department.
- 5) In the fifth step the resilient strategy roadmap is established. The scenarios, sell-by-dates and sequences are combined to design the pathways. A pathway as mentioned in the DAPP framework, is based on promising actions to avoid or overcome problems or to seize opportunities in different scenarios. In this research a pathway represents a resilient strategy.
- 6) In the sixth step the preferred pathways can be selected based on the preferred role of the Harbourmaster in the port-call-process. Two roles are visualised; the Harbourmaster as a facilitator or the Harbourmaster as a controller of the port-call-process.

Based on these six steps, the DAPP framework is used to design resilient strategies. It satisfies all criteria of a resilient strategy since it fits multiple scenarios with different impacts of digitalisation and automation. Actions contributing to long-term-objectives have been designed for the Harbourmaster to survive, adapt and grow in face of changes in these scenarios. In addition, by actively involving the Harbourmaster's organisation in the development of actions and by specifying the preferred pathways the roadmap satisfies the third criteria of a resilient strategy; its desirability by the organisation to implement. In addition, by including experts from the Port of Rotterdam in the third step when designing actions, effective actions will be created that contribute to the long-term-objectives. This excludes the need for establishing a monitoring system for contingency planning.

The final steps of the DAPP as designed by Kwakkel and Haasnoot therefore are not relevant in this research.

IV. RESULTS

This section presents the results of the research with respect to the research objectives. The first section discusses the current port-call-process and the areas of impact of digitalisation and automation. Section IV-B presents the final resilient strategies and how they are usable for the Harbourmaster.

A. DIGITALISATION AND AUTOMATION IN THE PORT-CALL-PROCESS

The port-call-process is divided in six sub-processes. These are organised by adequate information exchange

and a strong collaboration between the Harbourmaster, the Nautical Service Providers (NSP), the terminal, the vessel master and the shipping agent. Data from GPS, Automatic Identification Systems, cameras and (nautical) rules processed via IT-software, but also tacit knowledge serve as important source to make decisions in the port-call-process. The role of the Harbourmaster is to manage vessel traffic by gathering all information and services provided by the organisations and reporting all relevant information with the vessel master and NSP.

The port-call-process is an overarching process involving many organisations that all have their own procedures and interests. Additionally, the port-call-process is influenced by regulations and societal norms. The Harbourmaster has the mandate to facilitate the process and is obliged to report about the performance of the process to the State. For these reasons, defining the objectives of the Harbourmaster for the port-call-process is complex.

By taking into account both the performance indicators that are required to be reported to the State as well as the vision of the Harbourmaster, safety, in terms of number of accidents, and efficiency, in terms of vessel delays, are the most important long-term-objectives that are used as verification of the actions in the resilient strategy roadmap.

Digitalisation and automation have a direct and indirect influence of the port-call-process. Where digitalisation is the transition of analogue data and tacit knowledge to digital information, automation is by means of digitalisation, acquire data and human tacit knowledge so that the system can replace (partially to fully) human labour. These definitions result in the distinction of four levels of impact of digitalisation and automation; in the acquisition of information, the analysis of information, decision-support and decision implementation. The interaction between digitalisation and automation is illustrated in figure 4.

At this moment, a significant part of the port-call-process is

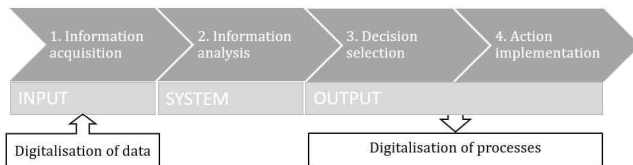


Fig. 4: Interaction automation and digitalisation

analogue and therefore directly affected by digitalisation and automation. An indirect impact can be found in three areas. Firstly it affects the long-term-objectives and challenges the capabilities of the Harbourmaster's organisation to achieve these objectives. Secondly, it affects all six sub-processes of the port-call-process and the applications such as IT infrastructure, sources of information and communication between the organisations. Thirdly, it affects the staff qualifications required to support the port-call-process.

Opportunities of the trend lie in a reduction of miscommunications, mistakes in sailing or guidance, and planning inaccuracies, threats lie in the risk of cyber attacks, IT dependence and a lack of support from the staff (Mansson, Luthoft, & Brooks, 2016; Newell & Marabelli, 2015; Smartport, 2018). Both opportunities and threats have their impact on the objectives of the Harbourmaster; safety and efficiency. The **speed** with which digital applications can be implemented is a relevant uncertainty which might lead to different impacts.

However, the specific impact in the port-call-process, including both opportunities and threats is uncertain. The speed at which developments in technology are applicable and the level of collaboration between organisation are deep uncertainties affecting this impact. Based on these uncertainties, four scenarios are created that evoke challenging questions, threats and opportunities in all areas affected by digitalisation and automation in the port-call-process.

B. RESILIENT STRATEGIES FOR THE HARBOURMASTER

The adjusted DAPP framework as presented in figure 3, section III, is applied to design resilient strategies for the Harbourmaster to anticipate to digitalisation and automation in the port-call-process. The developed scenarios contribute to the resilience of a strategy by generating a better understanding of the risks involved with changes in current operations that come along with uncertainties.

By means of a brainstorm-workshop with employees from the Port of Rotterdam an amount of actions is identified that seizes opportunities or addresses problems. The actions were processed into concrete actions for the Harbourmaster to be used in the resilient strategy roadmap. This resulted in a list of thirteen actions listed in table I.

TABLE I: Effective actions to be used in the roadmap

Effective action	Classification
1. Invest in big data analysis and algorithms	Seizing, hedging
2. Create 'data, systems and security' - department	Seizing, hedging
3. Communicate open and transparent	Shaping
4. Lobby for applicability of new technologies	Shaping
5. Set requirements for stakeholders	Mitigating, hedging
6. Reduction of port-tariff	Mitigating, hedging
7. Get insight in digital competencies	Seizing
8. Experiment with new technologies	Seizing
9. Publish standards used by the Port of Rotterdam	Mitigating
10. Risk management with stakeholders	Mitigating, hedging
11. Involve stakeholders in changes	Seizing, hedging
12. Collaborate with other ports	Seizing, hedging
13. Adjust staff qualifications	Mitigating, shaping

As some actions directly affect the objectives of the port-call-process, other actions focus on the impact of digitalisation and automation on the organisation of the Harbourmaster and the required staff qualifications. The latter ones mitigate uncertainties and reduce the chance of failure of other actions. The list of actions can be used in the resilient strategy roadmap.

A qualitative method has been used to assemble the pathways for the resilient strategy roadmap (see figure 5). The actions as listed in table I are used and their sell-by-date and sequence is assessed based upon literature review, expert interviews and the results from the brainstorm-workshop.

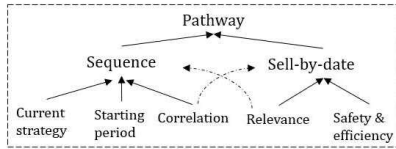


Fig. 5: Qualitative approach of designing pathways

The resilient strategy roadmap (see figure 6) shows actions that strengthen each other or can extend each others sell-by-dates (vertical lines). As some actions directly affect the objectives of the port-call-process (green pathways), some actions focus on mitigating uncertainties or reducing the chance of failure of other actions by focusing on changes required in the organisation of the Harbourmaster (blue pathways) and the required staff qualifications (orange pathway). In order to guarantee for resilience, the two most extreme scenarios are included in the roadmap. This shows that in the 'all hands on deck'-scenario, with a strong collaboration and rapid applicability of technology, actions concerning technology and organisational change are relevant in an earlier stage than in the 'rippling forward' scenario, with a weak collaboration and moderate applicability of technology.

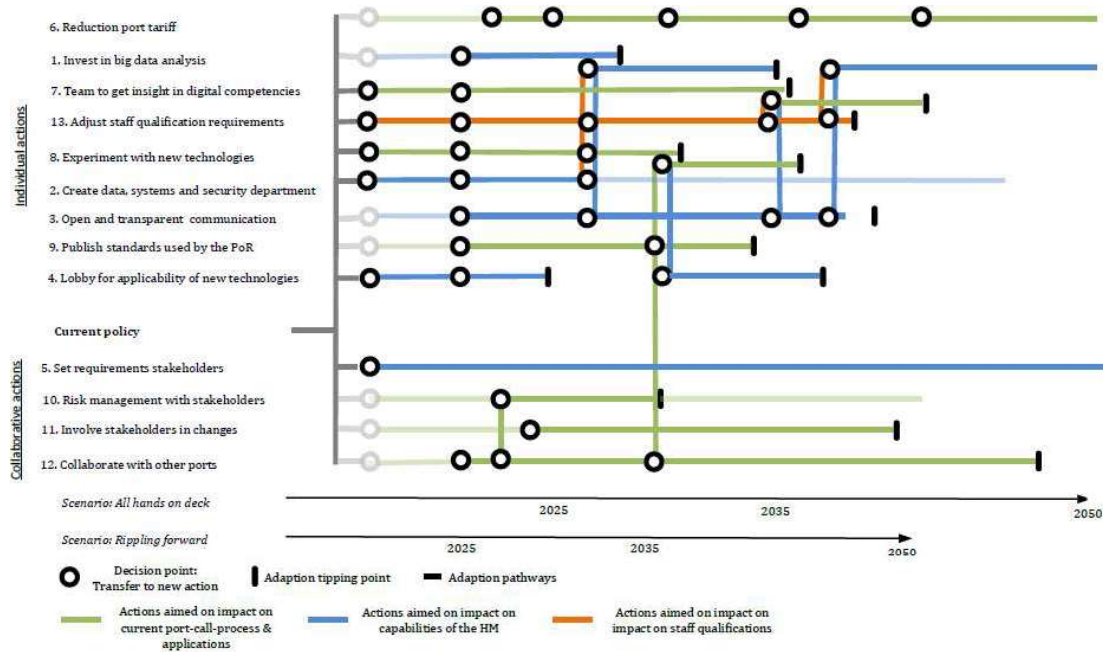


Fig. 6: Resilient strategy roadmap

The qualitative application of the DAPP method in this research has appeared to be a suitable method to develop resilient strategies. It has been found that there is not 'only one' resilient strategy for the Harbourmaster to anticipate to the impact of digitalisation and automation. An important note therefore is that the resilient strategy roadmap should be interpreted as a guideline and not as a strict set of actions. The contribution lies in the identification of the areas of impact of the actions with respect to the areas of impact of digitalisation and automation in the port-call-process. The Harbourmaster can use the description of actions and their correlations to identify actions that strengthen each other or mitigate uncertainties. Different combinations of actions result in different resilient strategies. However, it has been found that each combination of actions should include at least one of each type of actions to cover all areas of impact of digitalisation and automation.

V. CONCLUSION, DISCUSSION AND RECOMMENDATIONS

This section answers the main research question and discusses several recommendations based on the results of the research as well as the methodology used.

A. ANSWER TO THE MAIN RESEARCH QUESTION

This research has been carried out to help the Harbourmaster to respond and anticipate to the impact of digitalisation and automation in the port-call-process. From literature study no specific methodology was found to design a resilient strategy for such purposes in a structured way. To fulfil the aim, this research provides a structured approach to identify the impact of digitalisation and automation in the port-call-process as well as a qualitative approach of the DAPP framework to develop a resilient strategy roadmap. It thereby answers the main research question: *What are resilient strategies for the Harbourmaster to anticipate to the impact of digitalisation and automation in the port-call-process?* By answering this main question, there can be concluded that the qualitative application of the DAPP in this research therefore is a suitable method to develop resilient strategies.

The following list shows the characteristics of a resilient strategy and elaborates how the qualitative application in the adjusted DAPP in this research satisfies these criteria. A resilient strategy:

- 1) Helps the Harbourmaster to survive, adapt and grow in face of change due to the uncertain impact of digitalisation and automation.
In the first three steps, threats and opportunities of digitalisation and automation are defined in four different scenarios. A list of examples of concrete and effective actions is developed based on these threats and opportunities.
- 2) Guides decision-making towards the long-term-objectives of safety and efficiency in the port-call-process.
With the inclusion of a feedback loop, the designed actions are assessed based on their contribution to a safe and efficient port-call-process. Actions that did not contribute are not included in the final resilient strategy roadmap.
- 3) Is desirable by the organisation to implement.
Pathways in the resilient strategy roadmap are assembled qualitatively, based on their relevance and their relation to current projects. In addition, employees from the Harbourmasters organisation are included in the design of strategies and the selection of preferred scenarios.

It has been found that there is not ‘only one’ resilient strategy for the Harbourmaster to anticipate to the impact of digitalisation and automation. An important note therefore is that the resilient strategy roadmap should be interpreted as a guideline and not as a strict set of actions. The contribution lies in the identification of the areas of impact of the actions with respect to the areas of impact of digitalisation and automation in the port-call-process. The Harbourmaster can use the description of actions and their correlations to identify actions that strengthen each other or mitigate uncertainties.

Different combinations of actions result in different resilient strategies. However, it has been found that each combination of actions should include at least one of each type of actions to cover all areas of impact of digitalisation and automation.

B. DISCUSSION

The resulting resilient strategy roadmap shows similarities but at the same time also has a different purpose than the traditional DAPP roadmap. On the one hand, the strength of the DAPP method can be found in the resilient strategy roadmap since it stimulates the policy makers, such as the Harbourmaster, to include adaption plans in their planning, to keep the system headed towards the original goals (Haasnoot et al., 2013). On the other hand, the qualitative approach in this research, lets the roadmap serve as a tool to compare types of actions based on their qualitative impact and classification and to discover possible combination of actions that strengthen each other. The strategic objective and lack of quantitative data, results in a clear difference compared to the DAPP in the traditional format, where the intention is to determine how long decisions can be postponed. Therefore, in the resilient strategy roadmap the sequence of actions is leading compared to the original DAPP framework where the time component is essential.

There can be discussed whether a qualitative approach is sufficient to develop resilient strategies for other organisations. This might depend on the objectives, role and perspectives of the organisation. For policy makers, dealing with long-term objectives and operating in a slowly changing environment, a qualitative approach is assumed to be sufficient. Planners in more operational organisations or departments might prefer to know the exact quantitative impact of uncertainties and actions on short term. If necessary, a quantitative method to design scenarios, including threats and opportunities as well as generation of actions and establishment of sell-by-dates, can then serve as a supplement. In this case, to determine the success of actions and pathways, quantitative long-term-objectives are essential (Haasnoot et al., 2013).

Another matter for debate is the inclusion or exclusion of contingency planning (planning of additional actions in case the current actions do not contribute to the long-term-objectives). The adjusted DAPP framework used in this research to design resilient strategies, does not include contingency actions, which is opposite to the traditional DAPP. Since the resilient strategy roadmap satisfies all criteria relevant for a resilient strategy this is not perceived necessary. In addition, during the brainstorm-workshop, experienced strategists of the Port of Rotterdam assessed the developed actions based on their contribution to safety and efficiency. Therefore the identified actions are perceived to be effective. On the other hand, the lack of familiarity of the participants with the DAPP approach could be a reason to include contingency planning, to guarantee for resilience. In addition, contingency planning might be useful in case the participants in a brainstorm session are not experienced in the field.

As for the identification of areas of impact, it is expected that that for other organisations that follow the steps as presented in this research, similar areas of impact will be identified. This results in the understanding that in order to avoid threats that come along with digitalisation and automation of the processes, actions only can succeed if the organisation and staff qualification changes as well. However, the content of the process-related actions will differ due to different, case dependent, uncertainties and elements in the process.

C. RECOMMENDATIONS

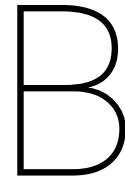
This research is built on several assumptions and limitations that lead to opportunities to conduct further research. Although the scenarios in this research have been verified by experts from different departments, it is recommended to establish scenarios in a group setting rather than on individual basis. This might result in an increase in organisational support or could lead to different scenarios and subsequently different actions to be used for the resilient strategies. In addition, to obtain a wider set of more valid, specific and consistent actions, it is recommended for future researches including a brainstorm-workshop, to reserve more time and to include a higher amount of participants stemming from different organisations. Lastly, the assembling of pathways in this research was done qualitatively, based on the sell-by-dates and relevance. In case other factors were taken into account, such as risks, costs, or availability of resources, other sequences of actions might be found. When a different research applies the DAPP in a qualitative manner, it recommended to investigate what factors are most suitable to use in that case.

The findings of this research lead to two important recommendations for further research. While literature shows that autonomous vessels are expected to have a radical impact on the port-call-process, during the brainstorm-workshop no problems were identified on this field and subsequently this aspect is not taken into account in the design of the resilient strategy roadmap. From interviews and literature study, there is no doubt that (variants) of autonomous vessels will be introduced within thirty years from now, resulting in major consequences in the transition phase where autonomous and conventional vessels interact. It is strongly recommended to investigate this further including aspects such as the impact on safety, efficiency and the changing role of organisations in the port-call-process. In addition, it was found that great improvements are to be made in the field of planning of vessels and NSP when terminal planning is included, resulting in synchromodal or Just-In-Time transport. Since this aspect was not included in the scope of this research it has not been taken into account. Therefore is it recommended to conduct further research to the opportunities of digitalisation and automation concerning the planning of terminals.

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RESEARCH METHODS

The answers of the sub-questions provide an integral analysis in light of the main research question. In this appendix more information about the research methods to obtain the answers to these questions is provided. Four research methods will be used within this research, namely; (1) Case study, (2) Literature research, (3) Expert interviews and (4) Scenario analysis.

B.1. CASE STUDY

In order to answer the first, second and fourth sub-question in depth research at the Harbourmasters department is required. At the port there is no standard day and it is an exception if a process is executed exactly as it is described in theory. A case study is an empirical inquiry that investigates the case from the researchers point of interest (Yazan, 2015). Robert K. Yin reviewed the case study method, its research design, the advantages, pitfalls and the ways to overcome them in his book 'Case Study Research: Design and Methods'. In a case study the central tendency lies within the illumination of decisions: why they were taken, how they were implemented and with what result (Yin, 2014). This is mainly the objective of the fourth sub-question and important to take into account when designing strategies for that fit in the decision-making of the Harbourmaster. Information about the current port-call-process, important stakeholders, tools they use, how the HM manages the process, makes decisions and deals with uncertainty are all aspects that can be retrieved from direct observations together with experiences from employees and access to documents. By doing a case study variations in program definition depending upon the perspective of different actors may be revealed. One of the traditional prejudices against the case study strategy is the lack of credibility of case study research. It happens often the case study method has led to biased views to influence the direction of the findings and conclusions (Yin, 2014). Therefore it is needed to pay attention to reduce the possible negative effect of the case study method on the quality of the results by reporting the information fairly and by verifying information with different employees at the PoR. Another common concern about case studies is that they provide little basis for scientific generalisation (Yin, 2014). The third major complaint about case studies is that they take too long and result in a huge amount of documents. To overcome this pitfall, it is important to have clear propositions since otherwise it might be tempting to collect 'everything' which is impossible to do. Numerous literature can be found that name the criteria for judging the quality of case study research designs. Important are the construction of validity, the external validity itself and the reliability. Validity can be constructed by using multiple sources of evidence, by establishing a chain of evidence and to have the draft case study report reviewed by the key informants, which in this case are Raymond Seignette and Harmen Dorsser (Yin, 2014). The external validity deals with the problem of knowing whether or not the results of the case study can be generalised which in this case means if the resulted roadmap is also suitable for other ports and their harbourmasters. Important to note here is that case studies however, can be generalised to theoretical propositions and the goal is to expand theories (analytic generalisation) and not to enumerate frequencies (statistical generalisation). A developed theory will serve as a template with which to compare the empirical results of the case study where these results lead to a broader theory. The last criteria is the criteria of reliability where the objective is that if later researchers followed the exact same procedures as described by an earlier investigator, they find exact the same results (Yin, 2014).

B.2. LITERATURE RESEARCH

To be able to answer the second, fourth and sixth sub-question, a deep dive in the existing literature is needed. An overview of all areas involved with the digitalisation of the port-call-process is required in order to identify where it affects the operations of the Harbourmaster. To identify which type of scenario analysis method suits best in this research, literature review has to be done to seek for benefits and disadvantages of the various methods. For the sixth sub-question it is needed to look deeper into decision making in an uncertain environment. Again, literature describes many ways to do so. It is the question which method suits this research best. The issues that are most important are looked at, then typical decision making approaches for dealing with these issues are considered. Subsequently, promising strategies to make decision can be selected and refined based on expert interviews. The main constraint of a literature research approach is that it can be too theoretical. In practice no process is executed exactly as is described in a book or article. Therefore information from the literature study needs to be verified with the case.

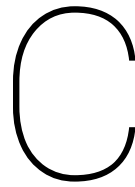
B.3. EXPERT INTERVIEWS

To be able to validate the results and retrieve in-depth knowledge, expert interviews are needed to give an answer to the second, third, fifth and sixth research question. Expert interviews serve as a tool to show how everyday practice of social research and theoretical consideration of this practice do not always run parallel to each other (Bogner & Menz, 2009). The aim of the interviews needed to answer the second sub-question, is to find out how both experts in the field of autonomous vessels as well as vessel-traffic management departments at the Port of Rotterdam think about the impact of this trend. Furthermore, interviews with various departments at the Port will lead to a diversity of Key Performance Indicators of the system, which will serve as input for the strategy development. No one knows the current system better than the operating departments at the Port of Rotterdam and therefore their vision on and verification of future states of the system is crucial. Interviews with different sections of the Harbourmaster's department are needed to identify which tools exist to act upon the changes in an effective, legitimate and adequate manner.

To structure of the interviews will be a combination between structured and open interviews, to give interviewees the opportunity to complement on the main questions, but ensures that essential information is gathered. Even though having interviews with the problem owner and experts will lead to designs that are close to the system, it is needed to be careful interpretation the answers, since it is possible they can be subjective or the interviewees interpret the questions differently. This drawback can be partly overcome by interviewing at least two employees per department or knowledge field.

B.4. SCENARIO ANALYSIS

To answer the main research question, it is required to know what might happen and change when the port-call-process will be automated. Information will be retrieved by means of a workshop session in which experts are asked to reflect on the results and provide their opinion whether or not they consider the scenarios to be plausible. Since autonomous vessels and their development is a relatively new topic, data is limited and therefore a qualitative scenario analysis method will be more suitable. Qualitative scenario analysis can capture development factors such as values, behaviours and institutions, providing a broader perspective than is possible from the quantitative method (Swart et al., 2004). The constraint however is that quantitative methods can offer mathematical algorithms that help map relationships with sufficient accuracy for simulation. This should be kept in mind when interpreting the scenarios. Scenarios can be made more realistic by for instance looking at other modalities that already implemented digitalisation and automation earlier.



INTERVIEW GUIDELINES AND SUMMARIES

Since the port-call-process is a complex process, in which many organisations are involved that exchange information from different sources including tacit knowledge, it is difficult to capture in literature. Insights gained from the interviews should shed light on all information that is not mapped in process descriptions, as well as a validation of the processes mapped. In addition, specific knowledge is retrieved from experts in the fields of digitalisation, KPIs, autonomous vessels and the tasks and duties of the important parties contributing to an efficient port-call-process. In this research an expert is someone who has substantial knowledge of the field of research and works with the topic on daily basis, is not afraid to deal with the uncertainty and has the power of imagination (Enserink et al., 2010; Lipinsky & Loveridge, 1982; Porter et al., 1991). The questions of the interviews are set up by the author of this research and have been checked and replenished by Raymond Seignette. All interviews are spoken in Dutch and are translated by the author. After each interview there is asked which questions the interviewee thought were relevant or missing. On forehand, the goal of the interview is made clear. Since all interviews are aimed on gaining more in-depth knowledge of the system, interviews are held with experts in many different fields, and therefore questions are not equal. However, the general trend of all interviews is the similar and discussed in the set-up of the interviews.

C.1. SET-UP OF THE INTERVIEWS

On forehand, the appointment for the interview was made oral or via email, usually two weeks in advance. A short summary (2 sentences) of the research subject and the relevance of the interview was described and the report introduction was attached.

1. **Introduction** - 5 minutes, introduction interviewer, objective of the research, aim of the interview, introduction interviewee, permission to record.
2. **Interview questions** - 50 minutes.
 - (a) General questions about the interviewees field of expertise - 20 minutes
 - (b) Questions about the interviewees view on the field of his expertise, problems that are happening and improvements that could be made - 10 minutes
 - (c) More specific questions about the interviewees view on digitalisation and automation in the port-call-process, the opportunities, threats and aspects that cannot be digitalised or automated - 20 minutes
3. **Closure** - 5 minutes. Conclusion and thank you.

C.2. PORT OF ROTTERDAM - HARBOURMASTER'S DEPARTMENT

Four interviews were held with employees from the Harbourmaster's Department. The interviews provided information used in the conceptualisation phase. Table C.1 shows an overview of all interviewees.

Table C.1: Experts within the Port of Rotterdam

Name	Job title
Jan Willem Verkiel	Manager of the policy department
Robert Molenaar	Advisor KPIs and processes
Willem Maan	Team leader HCC
Ed van Golden	Team leader of the VTS operator

C.2.1. STRATEGY AND POLICY DEPARTMENT - JAN-WILLEM VERKIEL AND ROBERT MOLENAAR

Jan Willem Verkiel is manager of the policy department at the Harbourmaster's division. He works for over 15 years at the Port of Rotterdam.

Robert Molenaar is advisor at the Harbourmaster's Department. He is responsible for managing the internal processes and alignment with the KPIs of the Harbourmaster's division.

Interviews were held with Jan-Willem and Robert at 12/11/18 and 22/02/2019 at the World Port Centre.

Goal Interview: Gather information about the vision and KPIs of the Harbourmaster's processes.

1. What is the vision of the Harbourmaster according to you?

The Port of Rotterdam is the smartest port. The users of the Port experience a Harbourmaster's organisation that is involved with their interests, with a constant eye on safety. Processes are aimed to be as simple as possible strengthened with smart information. In a rapidly changing environment the Harbourmaster's organisation is adaptive and innovative.

2. What is the definition of KPIs according to you?

KPIs are Key Performance Indicators. They are aimed on contributing to the aims of the organisation.

3. Who developed the KPIs?

The KPIs have been set up by the Harbourmaster in collaboration with the and are in line with the KPIs of the Port in general. In the end, it is the State Government who has the final word about the KPIs, this is according to the Havenmeesterconvenant. The Harbourmaster is executing his tasks as a joint-stock company which is a unique position. The government can ask question regarding the results of the KPIs each quarter of a year.

4. What are the Harbourmaster's KPIs?

I think it is important to distinguish the difference between the internal KPIs and the KPIs that we are accountable of reporting to the government. The latter one is about the performance of the port in general. These are the following:

- (a) *Nautical Safety Index (NSI). Expresses the proportion of actual, nautical safety with respect to the nautical safety in the reference period*
- (b) *Safety & Environmental Index (SEI). Expresses the proportion of the current safety with respect to the safety in the reference period. Safety in this context is about transportation- and environmental safety.*
- (c) *Nautical Efficiency Index (NEI). Is currently being developed and expresses the proportion of the actual total amount of time of the vessel voyage with respect to the norm of that voyage.*
- (d) *Water Pollution. The amount of spills of polluting liquids.*
- (e) *Claims. The amount of claims per year.*
- (f) *Port security. The average state of security of potential terrorism risk objects in the port.*

Though I think it is more important to look at the measures the Harbourmaster can take to improve or influence the safe, smooth and service; VTS, HCC, etc.

Internal KPIs are the KPIs per department, per task, per job. What are measurable indicators you can control and check. For instance, time between NOA and administrative clearance, delays, response time, etc. I think these are the most important KPIs. These are the factors the Harbourmaster can influence. However, until today, they do not exist. I think productivity can use an enormous boost with the introduction of the internal KPIs. A year ago, a start has been made to establish the indicators. Four main

processes were defined: Planning, Traffic, Incident Prevention and Maintenance and Control. Within these processes, KPIs can be defined and checked with the impact of digitalisation

5. Do all KPIs have the same weight?

Yes, they all have the same weight. But in my opinion, safety is the most important KPI.

6. To whom is the Harbourmaster required to report its performance?

The KPIs are reported each quarter of a year to the Government. The government can ask questions about certain scores of the indicators. Which measurements are taken? How is the Harbourmaster going to improve the score?

7. What are the consequences for the Harbourmaster in case the target indicators are not reached?

In case the Government is not satisfied with the results of the indicators they can take measurements the Harbourmaster has to follow. But this never happens. The State does not have enough specific knowledge about what we do and therefore it is hard for them to control the indicators. Due to too many reasons the targets might not be reached. These can also be reasons of events that the Harbourmaster is not accountable for. Everything that can happen resulting in a voyage of a vessel is much more; weather, role of the vessel master, role of nautical services, etc.

8. How are the KPIs developed?

The Harbourmaster created the KPIs and the Government approves them. Via the Plan do Check Act cycle we continuously look for improvements to make. Past years we started focusing more and more on this cycle; we established KPI teams, who's task is looking for developments and ways to improve performance.

9. Are the HM KPIs in line with the stakeholder KPIs?

I don't think this is the case. For instance, tugboats want to help as many vessels as fast as possible. The main priority at the nautical services is money. Indirect their KPIs are important for our KPIs, but not matter when, safety is always inferior to safety.

10. What are the ways the Harbourmaster can influence processes to improve KPIs?

In the VTS department a lot is done to influence the KPIs. The amount of traffic commands (could also be a KPI), the amount of consultations with a party, the time it takes to give the correct information, the time it takes for a PVT to get to the event all are important.

11. Do you think KPIs will change due to digitalisation and automation?

Yes I think and hope they will change. VTS guidance will change since a large part of the VTS traffic will be automated which leads to a reduction in the amount of traffic instructions because the system now can react to it. The HCC too, the time it takes to give clearances will decrease.

12. What is the vision of the Harbourmaster?

Safe, smooth and service

13. Will this vision remain over the next 20 years?

Yes, this vision will hopefully never change. Safety will always be important. The only thing that will change is the definition of service

C.2.2. HARBOUR CONTROL CENTRE - WILLEM MAAN

Willem Maan is team leader of the Harbour Coordination Centre and product owner of Avanti. He is active in the Harbour Control Centre Next Generation programme and highly involved with the automation and digitalisation of the HCC processes. An interview was held with him 23/11/18.

Goal of the interview: To gain an understanding of the activities of the HCC, the problems they are facing and their view on digitalisation and automation

1. What are problems with communication systems the HCC uses?

The HCC only has contact with the vessel master, not with the agent. VHF does not always work. The vessel master sometimes switches it off or to the wrong channel. But it does not happen that often and there are always other methods to communicate with the vessel master.

2. What are the reasons of dangers and delays?

Biggest problems that occur is that the NSP do not have enough capacity. But real dangers? No. We always make sure that for instance two large vessels do not sail to the same curve in the canals at the same time. And some older or smaller vessels do not have AIS, but we have radar so we can see where vessels are.

3. What are problems that occur at the HCC in the port-call-process?

Many procedures are performed twice. For instance: When a vessel enters the Maasaanloop he makes his first operational contact. The VTS operator asks for his depth, even though this is already visible in HaMIS. Why he does that? Because the vessel master knows this best. We only get this information from the agent but in 10 per cent of the cases there is a difference.

4. What are the KPIs of the HCC?

We do not work with KPIs. Only the SEI, NEI and NSI apply.

5. What is the role of the Harbourmaster in the future?

I do not think the role of the Harbourmaster will change that much. They will remain responsible for a safe and smooth completion of vessels in the port. Only the organisation, and especially the operational part will be much smaller. All analogue information will slowly transform into digital information.

6. What is according to you the role of the HCC in the future with respect to digitalisation and automation?

First we have to seek for opportunities. I think later on more analytical skills are required to manage and control all data. In the end, the HCC operators will get a role which is more management by exception. To only interfere when the system cannot do this. There will be less people needed. I think in ten year we can do our job with 25% less people. In such a complex and dynamic environment as a port I do not think you can automate all processes. There will always be a human factor to respond to effects such as wind and mist.

7. Which projects are currently being developed?

Static and dynamic assessments in Avanti.

Electronic ordering of vessels. At this moment, the agent will insert the full port passage plan of the vessel in PCS which is visible to the HCC. The HCC calls to order the vessel, with a certain depth, with pilot, boatmen, etc. But it happens regularly the HCC operator forgets to indeed order the vessel. From January 2019 the agent is in control of ordering the vessel and ordering NSP at the time he wants.

Dynamic scope assessments: real time maps with depth and tide levels. The time slots can be distributed automatically. This can be done 24 hours in advance with static information and 36 hours in advance with dynamic information.

8. Which functions of the HCC will always need humans?

There will always be a human factor in decisions which you cannot automate. You will be less flexible. An example: a vessel needs to berth but rules require that vessel with a length over 180 meters cannot moor at a buoy. The vessel master thinks something is wrong with the vessel and wants to only moor for 2 hours to sent a diver. If the weather is good, it is perfectly safe to moor a vessel of 185 meters to a buoy. But if the wind raises, it is not desirable. These are choices a HCC operator makes that contribute to the flexibility of the Harbourmaster.

C.2.3. VESSEL TRAFFIC SERVICE - ED VAN GOLDEN

Ed van Golden is the team leader of the VTS operators of both the VTS station Rotterdam and the station in Hook of Holland. He has been VTS operator for over 25 years.

Goal of the interview: In-depth information gathering about the daily tasks of the VTS and the problems they are facing and its view towards digitalisation and automation of its processes.

1. What would make the daily job of a VTS operator easier?

Maybe less communication.

2. What is the main cause of incidents in the port-call-process?

Inattention, human mistakes. VTS operators are responsible for 1/10 incidents. Weather, moist, heavy sea are all things hard to handle.

3. **What medium you use most to have contact with vessels?**
VHF via mariphone.
4. **What are problems you are phasing in the contact with vessels?**
Channels were closed down. Vessel masters did not know which information was intended for them. Too much information. In addition, the language barriers. The communication is Dutch. Often this goes well 9/10 times it is oke, sometimes the VTS operators sees for instance a vessel is not reducing speed when they are getting close to a harbour where another vessel is departing. In this case the VTS operator calls the vessel master by phone.
5. **What additional data and information would you want to have?**
Better sensors, better AIS data, planning information. Night vision cameras. Infrared. AIS is working, but complete radar coverage would be the most helpful. But anyhow, water, fog, wind remain a difficult factor. Besides, not all vessels have radar and AIS.
6. **Which organisation in the port-call-process is causing the most troubles?**
The terminal. They cause the delay because they wait for that last container to be on board of the vessel. The cargo is not on time. The delay will remain, only the information about the delay could be provided in an earlier stage.
7. **Are you responsible for the provision of information with regards to occupied berths?** Who is providing you with this information?
Yes, we know when a berth is occupied. We can tell a vessel to have a slower pace or to have its temporary berth outside of the port.
8. **Do safety issues arise concerning dept and inspections?**
No, almost never. This has all been calculated based on time windows and waves and currents. I cannot remember a time when a vessel was stuck to the ground. But if it happens, it is human error.
9. **How many times do collisions happen?**
I do not have the counts. I think there are 150 incidents in a year, but this could be everything.
10. **What information is unnecessary?**
Inexperienced VTS operator tells too much. He sticks to the procedures. Elder, experienced VTS operators have their own tricks to guide vessels with less words, but the same information. Most important is that the port-call-process still is safe. Only the vessel masters have trouble with the amount of information on the channel.
11. **Does the VTS have trouble with the shift in elder, more experienced operators to the new operators?**
Safety never will suffer from the fact that there is a shift in the experience of operators, nor is efficiency. The only thing is that the new operators don't have the tacit knowledge and the smart ways to maintain the same level of quality without that many words. This causes for much rustle on the VHF channel and the vessel masters are complaining about this.
12. **Does the VTS have KPIs? What and how do you measure?**
No, we do not have KPIs. The goal is to guide the traffic safe, smooth and secured. There is no priority in these goals.
13. **What is safety according to you?**
To do our job in such a way at the end of the day no accidents have happened.
14. **Who is controlling your tasks and duties?**
I am in charge of the VTS Botlek and VTS Hook of Holland. We have assessment meetings and we listen to the VHF-conversations. When incidents happen, the Harbourmaster is asking us about the situation and the role of the VTS operator in this incident.
15. **Do you think VTS can be fully digitalised and automated?**
Information about occupied berths and voyage planning will be digitalised and available in the future. VTS is only monitoring, managing by exception. Vessels will sail based on AIS and the VTS will only interfere when required.

16. What AIS data would be useful to have for the VTS operator?

All movements is a vessel expects to make. He fills in AIS data. He knows where the vessel is going. Sometimes it happens the terminal contacts the vessel master whether or not it is possible to pick up a piece of cargo last minute. In this case it happens the vessel turns and picks up the cargo. The VTS operator does not know about this cargo pick-up but has to facilitate the master in his voyage. This is only short sea, but is sailing in the same traffic channels as deep sea vessels.

17. What will be the biggest impact of digitalisation and automation for VTS?

Less people. Now there are 85 VTS operators.

18. Do you think inspection and PVT can be fully autonomous?

I do not think they can ever be fully autonomous. But I think they should be together and serve both roles. Physical inspections are needed to have a secured port. In addition, somebody has to be on board. It makes an impression when an inspector in costume enters the vessel.

19. Do you believe in autonomous shipping? What will be the role of the VTS operator?

Yes, I think in fifteen years autonomous shipping will be normal. The role of the VTS operator will still be existing, maybe in a different format. For instance as the role of IT specialist as in the movie of Rolce Royce.

C.3. EXTERNAL INTERVIEW SESSIONS

Four external interviews were held. Interviews with the Nautical Service Providers were aimed at understanding their experiences and perspectives on the port-call-process and digitalisation and automation. In addition, information from the interviews was used to analyse their roles and to what extent the NSP experience similar challenges as identified in the interviews with the Harbourmaster. Rudy Neegenborn was interviewed to gain more understanding of the future of automation in the port-call-process.

Table C.2: External experts

Name	Job title
Erik de Neef	Director of the KRVE
Harry Tabak	Senior Maritime Pilot
Tjitte de Groot	Member of the board of the Pilot organisation
Elco Oskam	Member of the board of the Pilot organisation
Martijn Drenth	Member of the board of the Pilot organisation
Rudy Neegenborn	Full professor Multi-machine operations & Logistics

C.3.1. BOATMEN ORGANISATION - ERIK DE NEEF

Erik de Neef is the director of the Koninklijke Vereniging Roeiers Eendracht (KRVE). Two interviews were held with him about the current process, improvements to make and his view on digitalisation and automation on the boatmen process. These interviews were held on 13/11/18 in his office.

Goal interview: To get an understanding of the operations of the boatmen organisation and their view on digitalisation and automation.

1. What are problems you face in the current process?

I separate two processes in the port-call of a vessel. The navigation process, for which the VTS is partly responsible, and the manoeuvre process, for which the boatmen are important. We have enough manpower so if doesn't happen we are not available to help when a vessel asks us to (this in contrast to the pilots and tugs). At this moment, on average, berthing takes between 60 and 90 minutes which is too long. Event though the boatmen in the Port of Rotterdam are leading and one of the most efficient in the world (Singapore takes on average 30 minutes longer), there is always room for improvement. When a vessel arrives at the quay wall, it does not know the exact location, accurate on the meter, where it will berth. Therefore the boatmen have to wait till the crew of the vessel lets down the lines. Until then, the boatmen do not know what lines to moor first and where they will hawsehole the lines will drop. This causes inefficient work. Secondly, there is no control or monitoring from the Harbourmaster when the vessel is moored. So when weather conditions allow it for the lines to break or let go, the vessel master is responsible and often the boatmen are not on time and the vessel is loose.

2. What are improvements to make?

It would be helpful to digitalise the port call. When a vessel arrives, the captain knows the exact location of the berthing place on the quay wall. This data should be available for the boatmen at least 2 hours before berth. The vessel master is responsible for the mooring plan. This should be made available to the boatmen and should include the material of the strings and their casing, the break strength, the year it has been made, and the exact locations of the manifold, hawseholes and length of the vessel. A step further will be this, together with the weather conditions, wave height, locations of boulders on the quay will serve as input in a database/programme which then defines the best way to moor the vessel.

Another improvement to make which can contribute to a better Just In Time service will be a 'crowd measurement'. When knowing an range of the number of arriving vessels the boatmen can better assess the number of workers needed and be faster on location.

What could be an improvement too, is the real-time monitoring of berthed vessels by the Harbourmaster/HCC. When they react pro-active, less vessels will get loose. To do so, smart boulders are needed, measuring the forces on the lines real-time. The HCC will get notified when the situation gets critical and can inform the vessel master and boatmen. By doing so, a pro-active reaction can be achieved. Besides this, data about the specific berthing locations can be measured. Frequencies about the locations that often cause trouble, the vessel types, weather circumstances all can contribute to react smarter.

When implementing these improvements with help of digitalisation, I think the profit in time can be 30 minutes. Important to note is that not the whole process can be digitalised all at once. First digitalisation of the data we already have is needed, next a standardisation and finally new forms of improvements can be thought of.

3. What do you think of autonomous vessels in the boatmen process?

Of course we thought about it. I do not think fully automated vessels will happen, pilot on wall navigation will happen, but there has to be a technician on board all the time. Autonomous berthing is not plausible. It has been tested though. The vessel was moored with some sort of vacuum/magnet mooring system which consumed a huge amount of energy. But it turned out, the lateral force on the vessels was too high and the mooring system could not hold it. Tug boats were needed to get the vessel back and they got moored with the traditional lines for safety. I think there is a overestimation of the technical capacities. Besides this, I think autonomous shipping is susceptible to cyber-attacks and terrorism sooner than traditional vessels. Nobody can control who is boarding the vessel. How do you overcome a hacked vessel that is destined to sail right in to the harbour? Besides this, it is hard to stop a vessel when a dangerous situation occurs. The weight of the vessel, the current together with the forces on the propeller will cause turns that are hard to manage. Besides this, I think it would not be smart for the Port of Rotterdam to invest in autonomous vessels and take the lead because in the end, the other ports will think 'well nice you did research, we copy'. Autonomous sailing in inland shipping will be better to manage because of lighter vessel weights and currents that are not that strong.

C.3.2. PILOT ORGANISATION - TJITTE DE GROOT, ELCO OSKAM AND MARTIJN DRENTH

Martijn Drenth is member of the board of the pilot organisation and has been a maritime pilot for over fifteen years. He plays a role in upcoming initiatives for the pilot organisation related with digitalization and autonomous shipping. Elco Oskam is a member of the board of the pilot and organisation and manager operations and responsible for the planning and assignment of pilots and tenders. He has been a pilot for over fifteen years. Tjitte de Groot is a member of the board of the pilot organisation as well and has been a pilot for over 20 years.

Goal interview: To get an understanding of the role and processes of the pilot organisation, their relation with the Harbourmaster and how they anticipate to a changing environment.

1. What are problems you face in the current pilot processes?

The main problem we face in our duties concerns the planning and assignment of our pilots. We get notified 2 hours before the vessel needs a pilot so we have to handle immediately and sent a pilot to the vessel. For inbound vessels, often it appears the terminal is occupied, or the market is changing, so the vessel has to stay or return to its anchor place. Our pilots already often are on board of the vessel or at the pilot station at sea. This happens to 30-40 percent of the inbound vessels. For outbound vessels, the

terminal does not let us know on time when they expect the vessel to be ready for departure. This too gives high pressure on our capacity. Per day the number of pilots needed differs from 130 to 180. It would be nice to have better view on capacity needed on forehand.

2. What are improvement that can be made?

The problem described is all based on the information provided to us, mainly by the terminals. The agent at this moment has information about the vessel, the terminal, the cargo and time-slots. If this information would reach us sooner, we can make a more efficient planning. This mainly is the case for container terminals, since the container vessels often wait for that one last container. A roadmap together with the Harbourmaster, combining terminal planning and HaMis would help us. The APM terminal is already willing to exchange more information, due to the Just-In-Time performance of the vessels.

3. How do digitalization and automation play a part in these improvements?

At his moment we are busy digitalising many aspects of our task. We work with the electronic ordering of the NSP. Our vision towards digitalisation and automation is that processes will not fully be autonomous. We see it as a decision supporting tool, in the end someone has to press the button. I think the agents will suffer the most and face the biggest disruption in their daily tasks. They might not be necessary in the future. I think the Port Authority/Harbourmaster and the pilot organisation have to work closely together. They both are have to oblige to the same laws and are aiming on a safe and efficient port-call-process.

4. What information is analogue at this moment?

At this moment, the pilot calls the VTS operator when he enters the port and the VTS operator calls the HCC. This is inefficient in our opinion. Also contact with the towing services and boatmen when (un)mooring a vessel are via mariphone.

5. Do you think the role of the pilot organisation will change in the future?

Yes the role of the pilot organisation will change, we cannot avoid this. We already are changing the qualifications required to become a pilot. Different competencies are necessary. This will be adjusted more and more in the future. In addition, we have so much tacit knowledge, we are trying to put this in the computer with simulation programmes. Maybe in the future, the pilot will guide the vessel from a distance, a shore control centre. However, I think the pilot organisation will always play an important role in the port-call-process. Only its role will change.

C.3.3. PILOT ORGANISATION - HARRY TABAK

Harry Tabak has a background in maritime technology, petroleum engineering and has been a pilot for twenty-five years. He is actively involved in many innovation projects from companies (Heerema, Kongsberg Gruppen) as well as universities (TU Delft, Erasmus University) and therefore has a broad knowledge about both the technical and practical field of automation in sailing. This interview was held the 16th of January 2019 at the World Port Centre.

Goal of the interview: To get insight in the potential of digitalisation and automation in the port-call-process and the potential for autonomous sailing.

1. How did the pilot organisation and the maritime world change over the past 100 years?

There has been a transition, but it was not big. The main processes still are the same. The pilot organisation now embarks the vessel with a laptop with detailed navigation. But the electronic map is still not available on the vessel itself. The regulations to implement this are created by the IMO. It takes years to test a standard version. The technique is available, risk assessments are not.

2. Can you elaborated more about the risks?

There are six types of autonomous vessels, standardised by IMO. You need a risk security that is fourfold in case a wrong decision has been made. There are an enormous amount of sensors required. Heerema has vessels with for instance 60.000 vessels, times four for the risk coverage. This is really costly and only beneficial for LNG vessels.

3. Do you think autonomous sailing will happen?

I think the construction cost of the vessel will be too high. The ship needs to be designed differently. There

is no business model. It is true you do not need accommodation for crew members, but you need an air conditioning system four times as expensive to regulate the computers. According to Kongsberg, it won't happen. Building costs are too high. The neural network will not pass risk assessments. At this moment a neural network has not an endless memory and it discards certain elements if it learns something new. Until now it is not clear what the network discards. The capacity of the computer systems is not big enough yet, but this will come in the future.

4. What do you think of shore based control centre or infrastructure needed

A shore based control centre is only relevant in de port, not at sea. You already need backup to reach the port.

Offshore vessels are further ahead because of the regulations concerning safety and the cost of the load that cover the cost of the vessel.

5. Do you think autonomous sailing is safe if all risk control measures are applied?

I am not sure. There has been no research done yet to see how many accidents have been avoided by humans. The most steps are taken in in technical failures, but the operator can be responsible for mistakes as well. I think pilots and VTS will always remain a risk control function.

6. In the berthing process, do you think there are opportunities to be seized due to digitalisation and automation?

I am not sure. In the JIP project there were experiments done with automatic berthing by means of magnetic systems. That does not work because of a lack of flexibility. Shore tension is a better solution. Another visualisation to be made is to moor the vessel with the help of a robot arm. But vessels are getting bigger and the problems this will bring are getting bigger too. It will take much more effort to keep the vessel parallel. I think in the end maybe you can bring the vessel in on a technical manner, but can you substitute the eyes of a pilot by a computer? Well i think this is possible. Defence already works with laser controlled cameras that can create a 3dimensional hologram.

7. How do you think tacit knowledge can be replaced by digitalisation and automation?

I think digitalisation and automation are needed to create a good planning tool based on completion and not based on encounters. If i sail a vessel the VTS does not provide me information about traffic intensity. This also includes the planning of terminals and their quay capacity. I think VTS can contribute this by adjusting their work division. Instead of a single area they need to cluster the areas of their control. But his is not inline with the interests of the pilots. They do not want to loose their autonomy.

This is an idea. The Pilot enters the vessel with his laptop and couples it to AIS and retrieves information from all vessels around him. He has radar and the information about the estimated time of arrival. Than he provides all information about his route plan. The traffic intensity is visible as well. However, the pilot organisation does not want to contribute to this initiative.

8. Do you think this improvement is plausible if the pilot organisation refuses to cooperate?

No. I think this will not work. The pilot organisation is unreliable. Sometimes they want to cooperate and sometimes they do not.

C.3.4. TU DELFT - RUDY NEGENBORN

Rudy Negenborn is a full professor 'Multi-Machine Operations & Logistics at the TU Delft within the Department of Marine and Transport Technology and has a strong focus on autonomous shipping. He contributes to many different research projects and innovations projects for autonomous vessels. The interview was held the 12th of December 2018.

Goal of the interview: To gain information about autonomous sailing, the challenges, opportunities and the readiness level.

1. What is according to you the definition of autonomous sailing?

There is not one definition. For me it is a vessel without anyone a board steering or operating it. Autonomous does not have to mean unmanned. And unmanned does not have to mean autonomous. A ferry for instance, there are always people a board. Therefore i would always speak about levels of autonomy. The role of the human operator on board of a vessel changes. Digital systems take over more and more. Autonomous vessel you don't need human influences. Sometimes it can call upon the help of a human. Still it is an autonomous vessel.

2. Do you think autonomous sailing has potential in a port environment?

Yes. I cannot tell when. Cappelle looked into technology readiness of vessels. What technologies are available and what level are they at. We looked into that. It depends on the port of Rotterdam, if they want to build, it can go faster.

3. What is the biggest advantage of autonomous sailing.

The expectation is costs of salary of crew decreases, safety increases, transport will become more sustainable and there will be more capacity on board of the vessels. In addition, the relation between other transport modalities is important. If you know how to sail the vessel efficiently, maybe it is possible to bring more of the transport from road to water.

4. What are the main disadvantages?

For me there are not that many disadvantages, every disadvantage leads to things you can improve. The biggest disadvantage is that much is unknown; the technique, the impact, the interaction with other vessels, the changing roles, etc.. You are not sure if you can realise all advantages.

5. In what you can relate autonomous driving vs autonomous sailing.

In a way it is the same, you need sensors. A car can brake and it stands still, a vessel cannot. On the road you need to react fast, on water you need to anticipate long time in advance. Less users on the waterway.

6. What data is needed first to support autonomous sailing?

The actual position of the vessels. Not sure if AIS is accurate enough. And not every vessel has AIS, it is not always available. Every vessel needs his own orientation and the form as well. Needs to be in AIS data as well. Large small vessel. In some areas in a port I can imagine you can have the infrastructure. But not along the whole Rhine river. Tugs you need at all times since large vessels are not that manoeuvrable. But this will be supported by electronic systems. Tacit knowledge takes time to. Software on board of a vessel gives an advice and a human operator on board presses the button. The people with experience are important. Autonomic mooring systems is not working for all vessels, depending on size, currents. Under what circumstances is it possible.

7. What is the best way to mix autonomous traffic with traditional?

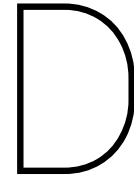
We do not know yet. Research is now aiming on knowing what information they need to exchange with each other. If you have 1 human sailed vessel, you might need the COLREGS, but if you do not have that, maybe you do not need this, and the vessels can make use of the water more efficiently. And if the planning of the terminals gets integrated sailing will be more efficient.

8. Do you think that if the HM does not invest in autonomous sailing now, they will suffer from the competition of other ports in Europe?

If they want to stay frontrunner, it is important they invest in research and projects. Not specifically in infrastructure, more in facilities and innovations contributing to the research.

9. What are the low hanging fruits to speed up autonomous sailing?

Those are not existing anymore. The only way ports and harbourmasters can contribute is to support research, innovations and experiments. Collaborating with knowledge institutes will help to speed up the process.



ACTORS INVOLVED IN THE PORT-CALL-PROCESS

In 2017, Sander Verduijn (TU Delft) together with Raymond Seignette (PoR) and the relevant stakeholders, mapped the relations between the different actors in the Port of Rotterdam. The aims, duties and more information about the organisations involved in the port-call-process are explained briefly in chapter 3 and more extended in this Appendix. Information have been withdrawn from Sander Verduijn's thesis, the Port of Rotterdam website and is verified with several employees at the Harbourmasters Department (Verduijn, 2017).

D.1. VESSEL

The master of the vessel changes per situation. The vessel is mastered by two entities. The captain, who sails the vessel, and the shipping agent, who is on shore and can communicate easier with the other organisations. The shipping agent is the representative of the vessel in the port and takes care of arrangements and shares the information with the relevant parties. He or she makes sure that services such as the pilots, tugs, bunkering and waste-disposal are ordered. It appears that the voyage planning of the vessel in coordination with the traffic planning and deployment of the NSP often not is aligned with the concerted planning of the NSP (Seignette, 2010). Vessels have been classified in 8 categories. Pilots and tugs have specific knowledge for certain vessel types and therefore cannot serve all types of vessels. Boatmen are trained to serve all types of vessels (see table D.1).

Table D.1: Classification of vessel types

Vessel type	Length (m)	Depth (m)
1	<120	
2	120-200	
3	200-300	
4	>300	<14,3
5a (Maasgeulers)	>300	14,3-15,5
5b (Maasgeulers)	>300	15,5-17,5
6 (Geulers)	>300	>17,4
7 (LNG Carriers)	max. 315	max. 13
8 (RoRo)	max. 215	max. 7

D.2. NAUTICAL SERVICES

The nautical services are the pilot organisation, the tug-organisation and the boatmen.

D.2.1. PILOT-ORGANISATION

Pilots guide the vessel into and out of the Port and its harbours. In this research, the relevant pilots are serving in the region Rotterdam-Rijnmond, the largest and busiest region with most pilots (Verduijn, 2017). Vessels longer than 75 metres are obliged to take a pilot on-board if they want to sail in the Port of Rotterdam. The pilot boards a vessel before it enters the Port and will from then on guide the vessel to her berth. By doing this in a safe and efficient way, the pilot cooperates with the tugs, the boatmen and the Harbour Master. Pilots have various degrees of qualifications regarding the vessel-type and -size they may pilot. Within the pilot-organisation, three main processes take place (see figure D.1). The first process is the 'Plan Deployment', in which the proper pilot is selected for the vessel at the right time. Depending on the weather-conditions and the vessel characteristics pilots will (dis)embark via a helicopter or a tender. In the special cases when, due to weather conditions pilots cannot be brought to the vessel, smaller vessels can be piloted from shore (Shore-based Pilotage) by a specially trained pilot from the Traffic Centre in Hook of Holland. In this case by using VHF the vessel is guided to the breakwaters of the port where the pilot can (dis)embark. The HCC and maritime pilot decide whether or not a vessel can receive SBP (Rotterdam Port Authority, 2018). Another option is that the vessel has to wait until no pilotage is needed anymore. This depends on the wave height. If the wave height is larger than 2.4 metres, for small shipping pilotage is required and for all ships pilotage is necessary when the wave height is larger than 3.2 metres. The second process takes place when the pilot has embarked the vessel and pilots it to its destination. In this phase the pilot and master discuss the plan of action and if there are any issues concerning the functioning of the vessel and if it is suitable for the port entry. Then the ETA is updated and if tugs were ordered, these will be (dis)connected when the vessel arrives at the tug-meeting point. The third process is the phase where the pilot instructs the boatmen and tugboats how to manoeuvre and (un)moor the vessel. The mooring lines are provided to the boatmen and if applicable the vessel crew tightens them with the winches on the vessel. The master of the vessel instructs the crew and is instructed by the pilot. When the vessel is moored, the tugs keep the vessel in position. When the vessel is safely (un)moored, the pilot calls 'gangway down'. The pilot keeps in contact with the VTS operators from the moment he embarks the ship till disembarkment. According to the VTS guidelines, he is obliged to report to the VTS operator in the various sectors he is sailing in (Seignette, 2018).

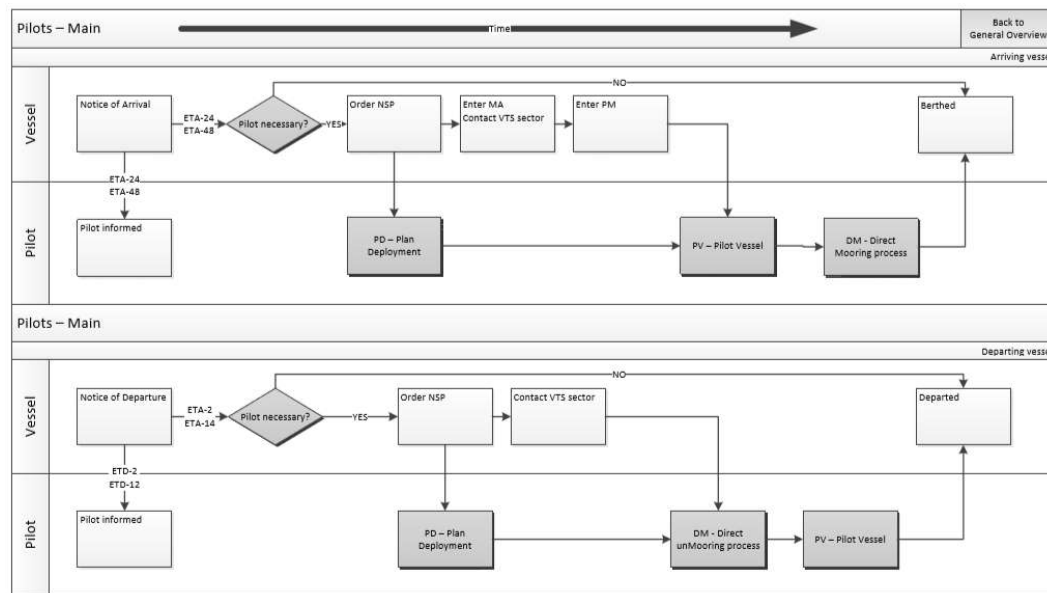


Figure D.1: Pilot-organisation processes: 3 main processes identified (Verduijn, 2017)

D.2.2. TUGBOAT-COMPANIES

Tugboats assist a vessel with manoeuvring in the Port and its harbours by either pushing or towing it. The two largest tug-companies in the Port of Rotterdam are Kotug Smit Towage and Fairplay Towage. Shipping companies often have a contract with one of the tugboat-companies to provide services every time one of their

ships requires it. Tugs usually meet the vessel near the entrance of the destined harbour, there they connect to the vessel and manoeuvre the ship towards the berth. Tugboats are not obligatory for vessels, unless the Harbour Master says so. However, practice shows that many vessels are not able to manoeuvre safely without help from tugs in the port in the same time span. As can be seen in figure D.2, within the tug-companies, two main processes can be identified. The first is the Plan Deployment phase where first the availability of the tugs will be checked and subsequently committed to an assignment. Different types of tugboats can serve different types of vessel classes. If a tugboat-company does not have tugboats available they will ask other tugboat-companies in the port. If there are not enough tugs available in time the vessel has to wait, which will cause delay in the nautical chain. Another cause of delay will be when the first available tug is far away and has to sail towards the meeting point first. The second process is the assistance of (un)mooring. In this process the tugs sail to the tug-meeting-point, connect with the vessel and assist it to her berthing place. Or in the case of a departing vessel, the tugs assist the vessel in sailing out of the harbour. The pilot instructs the tugs in connecting and manoeuvring the vessel. The arriving vessel will reduce her speed when the lines are connected. The duration of this process depends on the vessel class and berth location.

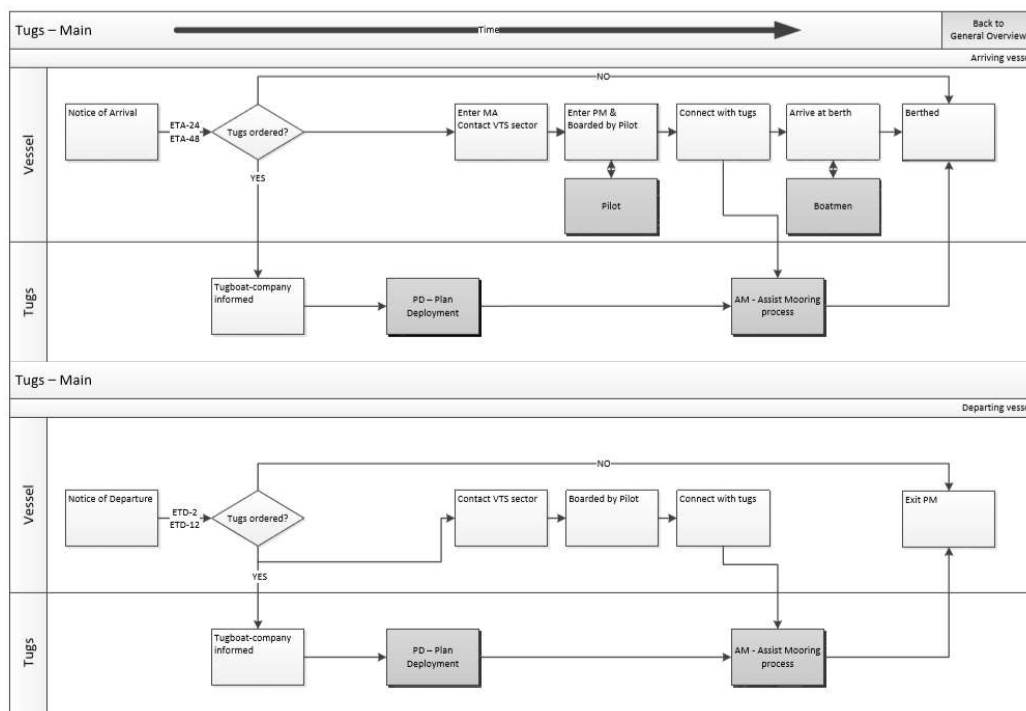


Figure D.2: Tug-companies processes: 2 main processes identified (Verduijn, 2017)

D.2.3. BOATMEN-ORGANISATION

In the Port of Rotterdam, the only boatmen-organisation is the Koninklijke Roeiers Vereniging Eendracht (KRVE). The boatmen-organisation is responsible for the (un)mooring of vessels. Provided with some exceptions, tankers and vessels longer than 75 metres are obliged to use the services of the boatmen. Two main processes take place in the boatmen-organisation (see figure D.3). The first is the plan-deployment, where will be checked if there are enough boatmen available for the assistance with arriving or departing vessels. All boatmen are qualified to assist in the mooring of all vessels. Since there are 280 boatmen in the port who work in teams of four to six, it almost never occurs that there are no boatmen available. The second process is the assistance of (un)mooring. This is done according to the mooring arrangement, which is set up for the vessel by the shipping companies and for the port by the Harbourmaster in collaboration with the boatmen (Seignette, 2018). The boatmen drive or sail to the vessel in a mooring boat where they collect the ropes of the vessel and bring them to the quay, buoys or jetty. In case there is no mooring boat available the crew will throw the lines ashore where they will be collected by the boatmen. Here they attach the ropes to the bollards. Except for the class one vessels, mooring boats and winch trucks driven by the boatmen are needed

for mooring the vessel when it arrives at a quay. A winch truck is a small flatbed truck with a small winch in the back to pull in the mooring lines from the vessel (Verduijn, 2017). If a vessel arrives at a buoy or jetty, only mooring boats are necessary. Boatmen also assist in the transportation of pilots by using fast vessels and taxis.

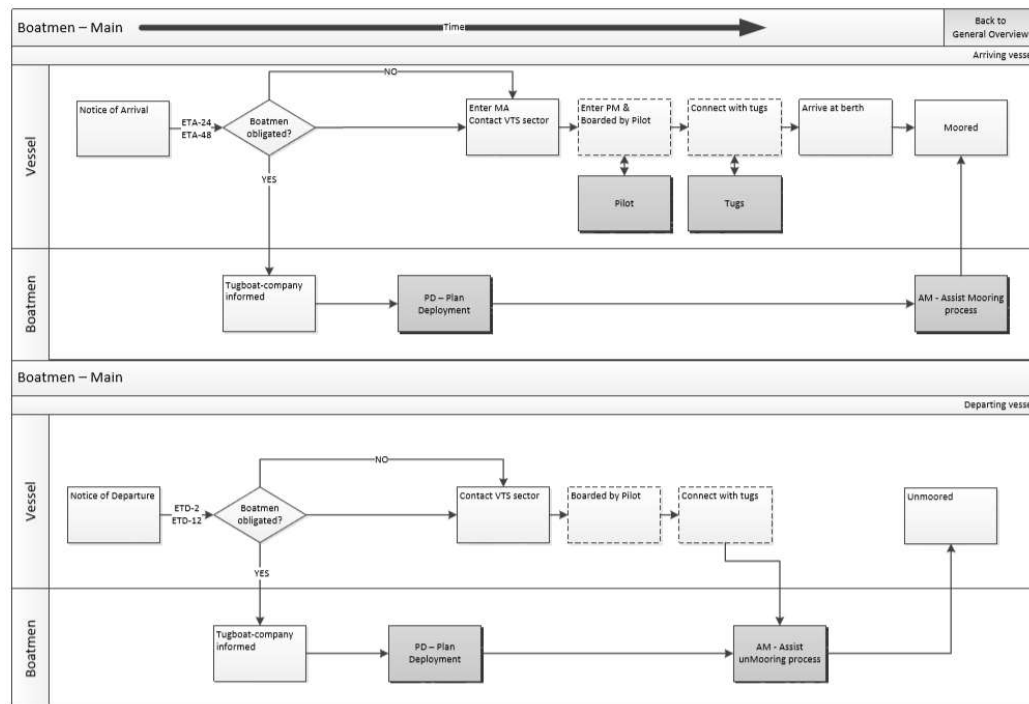


Figure D.3: Pilot-organisation processes: 3 main processes identified (Verduijn, 2017)

The boatmen of the KRVE are constantly trying to improve their services by implementing smart innovations. At this moment, the dynamic mooring system (ShoreTension®) is one of the special services boatmen offer. With ShoreTension®, vessels of any size can be firmly anchored to the quay because it significantly reduces movement caused by strong winds, currents, swell or passing ships. It exerts the same, constant tension to the vessel's mooring lines which are fastened to the bollards on the quay. The cylinder of the system hydraulically moves along with the forces which the mooring line is exposed to. By keeping the mooring lines at the same tension, also in case of swell, waves, wind and passing vessels, the vessels stays safe and stable. The boatmen are also responsible for the ships they use. Fenders that are used by the boatmen to (un)moor vessels and transport pilots are the responsibility of the boatmen. Fenders are constantly being developed to reach advantages on fuel and maintenance costs and speed. Besides this, they invest in innovative snatch blocks (friction free mooring), life jackets, winch units and buoys.

D.3. TERMINAL

The terminal plays a role as well in the port-call-process. The terminal is the starting or ending point of a vessel voyage. At the terminal activities such as bunkering, repairs, crew change and loading and unloading take place. The processes taking place at a terminal most relevant for the port-call-process are the long- and short term planning. Based on the contracts with shipping companies, the terminal is able to make a long term planning (mainly for line-services). This is not the same for all terminals. Oil terminals for instance react to changing oil prices. Based on the Notice of Arrival which include the ETA, the terminal is able to make a more precise short term planning. The vessel will receive a time window in which she has to arrive to keep the terminal planning on schedule. Between the ETD of the leaving vessel and the ETA of the arriving vessel, a two hour time window is required. This window gives the departing vessel time to get out of the harbour safely and anticipates for any possible delays.

D.4. HARBOURMASTER

Four departments and their processes relevant in the port-call-process are explained in this section. Figure D.4 provides an overview of the general responsibilities of the Harbourmaster's division .

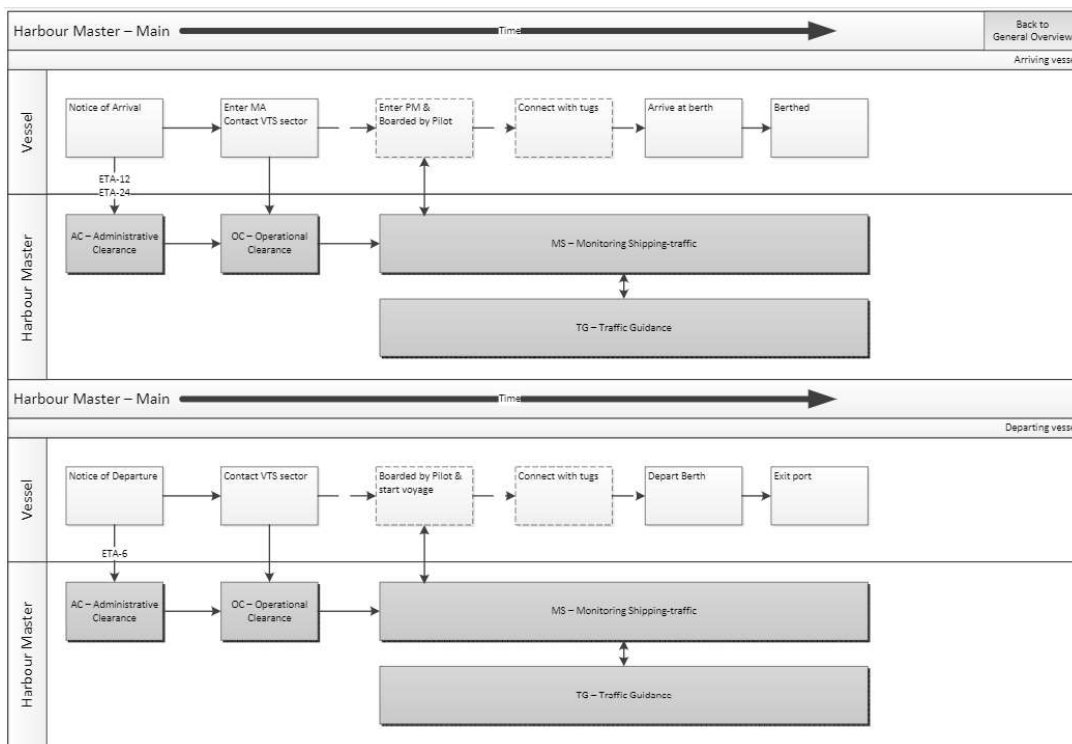


Figure D.4: Harbourmaster processes general (Verduijn, 2017)

D.4.1. VESSEL TRAFFIC SERVICE

The Vessel Traffic Service monitors all vessels entering and leaving the Port of Rotterdam. The operators track the vessels on their radars and maintain contact with them. They work 24/7 which means 3 shifts of 8 hours per VTS operator per day. Each operator has their own sector in the port to monitor and after one hour, the VTS operator will change to another VTS area. After administrative clearance, the VTS operator updates the port-call dossier based on received data from the vessel master concerning the actual draught of the vessel, its destination, ETA/ETD and if there is anything that requires extra attention. The VTS operators together with the HCC are in charge of the operational clearance of the vessel. In this process, there will be checked if the vessel has administrative clearance and if the data whereupon this clearance has been given still is up to date. It concerns possible incidents on the route. In case there are constraints, the VTS operator instructs the vessel and discusses further course of action. The vessel in this case can choose to drop its anchor in an anchor-area outside the port, in anticipation of operational clearance. VTS operators all have their own The VTS operator creates a traffic image of the actual traffic situation in his/her own sector. This image is derived from feedback of the VTS operator of the previous shift, from ARAMIS and from HaMIS data. The VTS operator assesses the real-time traffic image, keeping in mind the up-to-date hydro- and meteo-circumstances. In addition, short-term planning will be monitored to make sure no congestion or any potential dangerous situations can happen. Furthermore, the VTS-operator is responsible for traffic guidance. He or she prioritises (urgent, high, medium) in HaMIS which vessels need physical escort by patrol vessels based on potential and special circumstances. In case a vessel needs guidance which is not required to be physical, this can be done via VHE. When the vessel is berthed, the VTS-operator registers this as the Actual Time of Arrival (ATA).

D.4.2. HARBOUR COORDINATION CENTRE

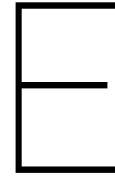
The Harbour Coordination Centre takes part in the administrative clearance of a vessel voyage. After the agent notified the arrival of the vessel, the HCC checks the NOA (Pre Notification of Arrival) on the following aspects: nautical, security, port health and nautical activities. Next the HCC tests to what extent the agent has satisfied the legal report duty for this port call by checking all information he has provided in the messages so far. If there is information lacking this will be told to the agent. When the HCC approves the NOA it registers the starting time and expected duration and ETA of the voyage. The HCC informs the Vessel Traffic Operators, Patrol vessels, Inspection and nautical services. The HCC is involved at the operational clearance of the vessel voyage as well. When there are significant deviations from the administrative information, the VTS operator will contact the HCC. The HCC will recheck the voyage and when it is approved it will be marked in HaMIS. Furthermore, the HCC checks the availability of the destination berth. Required is a two hour window between the arriving vessel and the vessel leaving the berth to overcome unwanted encounters when manoeuvring in the harbour (Verduijn, 2017). If there is help required from the nautical service providers (NSP) the HCC will check if the deployment has been planned. During the voyage the HCC and inspection will monitor the vessel and when the vessel activity is ended, the agent or master of the vessel will notify the HCC who subsequently registers the ending time of the voyage and informs the VTS department and nautical services. Another process of the HCC is the monitoring of the port. Whenever there is an incident or damage in nautical infrastructure, the HCC will get notified. In case of damage the HCC will check the situation and send patrol vessels to the location or gather information via the VTS. Based on all information available, the HCC assess the consequences for vessel traffic, the HM and the nautical services. The information will be passed through the owner of the object. Meanwhile the HCC will check the progress concerning the disruption. When the situation is solved the HCC communicates this to the relevant parties. In case of an incident the Veiligheidsregio Rotterdam will get notified and solve the incident. The last process of the HCC is to control vessel traffic activities and the berthing.

D.4.3. INSPECTION

Inspectors of the Harbourmaster's division check whether vessels comply with the shipping regulations concerning environment and safety. In the event of incorrect or unsafe actions, measures are taken. In addition, systematic checks are carried out to make sure shipping companies and agents comply with the statutory administrative reporting obligations (Havenbedrijf Rotterdam, 2016b). During the administrative administration of a port-call, apart from the HCC, the inspection is needed to check the safety- and milieu aspects as well as the nautical activities of the call, for instance the bunkering of the vessel. The inspection also plays a role in the supervision of vessels in berth and nautical activities. Physical inspections will be done by the Inspection in case the concerning nautical activities have been prioritised based on the administrative assessment. Depending on the nautical activity, the status of the execution will be monitored by the HCC or the Inspection. In case of doubts about the activities, they will contact the master of the vessel. The areas that ought to be inspected will be defined on forehand in case an inspection has been planned earlier and when the inspection is ad hoc the inspector will assess this himself. The inspector gathers all necessary information on forehand (data about the vessel, cargo, nautical activities and laws). The inspection will result in a Vessel Boarding Report. A non-planned inspection occurs in case the Patrol Vessels notice peculiarities concerning vessel behaviour, situation on board, port security and condition of infrastructure.

D.4.4. PATROL VESSEL

The patrol boats, RPA vessels, are responsible for inspection and enforcement on the water. If necessary, the patrol boats guide the vessels physically and assist vessels in the event of incidents (Havenbedrijf Rotterdam, 2016a). A vessel may require guidance. In case the guidance is physical, a patrol vessel (PV) will accompany the vessel during its voyage to provide guidance. The VTS operator communicates this to the PV after which a PV will go to the vessel at the designated time. During the physical escort the crew of the PV will continuously listen to the sector channel and report on the situation to the VTS operator.



BRAINSTORM-WORKSHOP

A brainstorm-workshop called 'Resilient port-call-process 2050' with employees from different departments of the Harbourmaster has been held to design actions to anticipate to the scenarios. This appendix includes the goals and set-up of the workshop. It also elaborates on the role of the facilitator of the workshop, since this is an essential element to achieve the desired results.

E.1. GOAL

The brainstorm workshop is organised to contribute to the development of resilient strategies. In order to achieve the desired results, the following objectives have been defined:

- Get insight into opportunities and problems in the scenarios, other than defined in chapter 6, section 6.2,
- Generate various actions the Harbourmaster can take to prevent or respond to problems and to seize opportunities in all four scenarios,
- Assign actions to a date and put them in a sequence, in order to be useful for a roadmap,
- Verification of contribution of the actions to long-term-goals,
- Get insight in the preferred scenarios and actions to reach these scenarios.

E.2. SET-UP

This section will describe the set-up of the brainstorm-workshop. In order to achieve the desired results the set-up of the brainstorm-workshop is of great importance. The tools and methods used to design the interactive workshop are described in appendix E. The design of the workshop is determined by the input needed to establish a resilient strategy roadmap.

Table E.1: Set-up of the Resilient Strategy Brainstorm-workshop

	Deliverable	Duration
Introduction	-	20 minutes
Round 1: Problems and opportunities	List of problems and opportunities per scenario	30 minutes
Short break	-	5 minutes
Round 2: Action	List of actions to overcome problems and/or seize opportunities	30 minutes
Short break	-	5 minutes
Round 3: Relevance of actions	Classification of actions contributing to long-term-goals	20 minutes
Round 4: Sequence of actions	Timeline of actions	10 minutes

Continued on next page

Table E.1 – *Continued from previous page*

	Deliverable	Duration
Round 5: Preference of scenario	Rating of desirability of scenarios	10 minutes
Closing and time for discussion	-	15 minutes

The workshop is divided in five rounds. Each round contributes to achieve the goals of the brainstorm-workshop. The rounds and their deliverables are shown in table E.1. The total duration of the workshop is two and a half hours. After an introduction to the topic, the four scenarios are shortly described. There has been chosen to present the scenarios during the workshop instead of on forehand to support a fresh view onto the scenarios. Since the scenarios are already verified and validated by several experts in chapter 6, section 6.2, they are presented as a set story, not open for adjustments. To avoid tunnel-vision and to support creativity when identifying actions, the set-up of the workshop has not been presented to the participants on forehand.

The introduction was meant to make all participants acquainted with the topic and the scenarios. This is important for the generation of relevant problems and actions. The challenging questions and identified problems and opportunities by the researcher as presented in chapter 6, section 6.2, were not discussed to avoid biased minds during the brainstorm workshop.

In the first round the groups were divided as presented in table E.2. Actions are only relevant if they help to overcome problems or seize opportunities. Therefore in this first round, all participants were asked to think about at least 10 opportunities or problems. The problems and opportunities were established by means of a brainstorm-session. By writing them down on sticky notes and sticking them on one of the cells on the posters they were obliged to structure them immediately.

The second round was meant to design actions, helping to prevent or overcome the problems and to seize potential opportunities. Again, this was done by means of brainstorm sessions. The participants were asked to assign at least one action to every problem.

In the third round, the actions were rated based on their impact on the most important aspects of the vision of the Harbourmaster; safety and efficiency. Since a resilient strategy guides a decision towards long-term goals, this is an important aspect. The actions were rated with a plus sign and a letter 'S' or 'E' if they contributed respectively to a Safe or/and Efficient port. A minus (negative), plus (positive) and 0 (neutral) indicated the direction of the influence.

In the fourth round, the actions designed in round two were assigned to a time-period. The sticky notes with actions were taken of the scenario-posters and replaced on the time-line. The results of this round give an indication for the pathways in the strategic roadmap.

The fifth and last round, was meant to stimulate a discussion about the Harbourmaster and the desired scenario. A strategy is resilient if it is desirable by the organisation to implement. Therefore this round is essential. The facilitator's role in this discussion is keep the discussion from straying too far off topic. To do this in the best way, the discussion was recorded so the facilitator could pay her full attention to this tasks.

The set-up of the workshop is not presented to the participants on forehand to prevent them from tunnel-vision and to support creativity when identifying actions.

Table E.2: Group compositions

	Scenario	Teams	Duration
Part 1	1	Participant A & Participant B	15 minutes
	3	Participant C & Participant D	
Part 2	4	Participant A & Participant D	15 minutes
	2	Participant C & Participant B	

Four participants were present at the workshop. More information about the participants can be found in Appendix E. Each round (30minutes), consists of two parts (15minutes). In each part, participants will brainstorm in groups of two about problems, opportunities or actions, for one scenario. Expected is that mixing

the groups after each part, will contribute to more creative ideas and will help to maintain consistency among the ideas generated per scenario. Therefore the first three rounds of the workshop are executed in groups of two participants (see table E.2). Yet, due to shortage of time and the availability of only four participants, the risk for inconsistency still remains for the scenarios that are brainstormed about in the same part.

E.3. PARTICIPANTS

The participants were invited to the workshop 1.5 month in advance. Six participants were selected and available the day the workshop took place. However, two of them cancelled the workshop due to personal circumstances. The four participants left were from different departments (table E.3).

Table E.3: Participants of the brainstorm-workshop

Name	Profession	Department	Experience
Raymond Seignette	Strategic Advisor Harbourmaster	Harbourmaster	>40 years
Harmen Dorsser	Program manager Harbourmaster Next Generation	Harbourmaster	8 years
Pieter Nordbeck	Advisor Nautical Research and Projects	Harbourmaster	9 years
Cees Deelen	Program manager Nautical Traffic	Logistics	>40 years

A mix between experienced participants and participants relatively new in the field has been chosen to cover both the traditional views on changes in the maritime world and the new, and innovative views on changes in the maritime world. This diverse set of perspectives will make a richer experience (Kaner et al., 2007). The participants all have a strategic mindset. To gain the most valuable results for the resilient strategy roadmap, only participants that are strategically oriented attended the workshop.

The participants were divided in two groups of two people. Each group consisted of an experienced and a relatively inexperienced participant. Table E.4 shows the groups per round. There has been chosen to shift groups between part 1 and part 2, to create a different dynamic per group. Due to the time and the amount of participants, each group was asked to brainstorm about problems, opportunities and actions for only two of the four scenarios.

Table E.4: Participants in groups compositions

	Scenario	Teams	Duration
Part 1	1	Harmen & Raymond	15 minutes
	3	Pieter & Cees	
Part 2	4	Harmen & Cees	15 minutes
	2	Pieter & Raymond	

E.4. THE ROLE OF THE FACILITATOR

Facilitating a brainstorm-workshop, requires specialised skills. The facilitators main role is to engage a group of participants in a social process of collaborative idea development (Nielsen, 2012). The facilitator should be knowledgeable about the process of the workshop while the participants are familiar with the content of it (Papamichail et al., 2007). To ensure that the workshop is productive, effective and efficient, various authors have described key factors relevant for facilitating a brainstorm-workshop in the preparation, execution and proceedings (Campbell, 1960; Coffey et al., 2003; Diehl & Stroebe, 1987; Kaner et al., 2007; Nielsen, 2012; Papamichail et al., 2007).

PREPARATION OF THE WORKSHOP

For effective brainstorming, it is essential to prepare the workshop. According to Coffey et al. (2003), the preparation starts by gaining some understanding with the basic ideas of the domain. All literature read and expert interviews held in the conceptualisation phase of this research covers this aspect. Furthermore, another important part of the preparation is the articulation of clear objectives for the session (Coffey et al., 2003).

DURING THE WORKSHOP

It is typically the case that participants will tend to stray from the focus of the session. The facilitator should keep the session from straying too far. Since the ‘Resilient port-call-process 2050’ workshop only has a duration of two and a half hours, this task is extremely relevant. In addition, it is the responsibility of the facilitator to make sure all participants have input in the session. Encouraging participants to write down every thought they have during the brainstorm might avoid withholding of ideas and prevents free-riding (Diehl & Stroebe, 1987).

Since facilitating a brainstorm-workshop essentially has two components, there can be chosen for an individual facilitator or a paired-team facilitator (Coffey et al., 2003). One could moderate the discussing, the other could record the proceedings as they unfold. To be able to cover both tasks with only one facilitator, there has been chosen to individually facilitate the workshop and process the results afterwards. This leads to the risk of reduction of new ideas to unfold based on processing the ideas instantly. To avoid this risk, all ideas will be written on sticky notes and placed at the corresponding scenario visible to all participants. The use of the sticky notes during interaction workshops is proven to stimulate cognitive actions. In addition, it makes it possible to externalise individual thoughts to enable communication between the participants (Nielsen, 2012).

PROCESSING OF THE RESULTS

When the workshop is over, the results should be processed effectively with regard to the desired input needed for the roadmap. The actions identified have to be structured and similar and overlapping actions have to be aggregated. In addition, causalities between actions have to be avoided. The processing of the results will be done in section 7.3.

E.5. TOOLS USED

Four different posters were taped to the wall, each corresponding to one of the scenarios. To structure the results, the scenarios were divided in four cells; ‘VTM’, ‘Infrastructure’, ‘Organisation’ and an empty cell to support own thoughts and interpretations (see figure E.1). Orange post-its were used for problems, blue post-its were used for opportunities and yellow post-its for actions. A timeline was designed as well to help visualise the sequence of actions. The introduction of the autonomous vessel was displayed on the timeline in the year 2035 since this is considered as an important new technology affecting both areas of the port-call-process; VTM and infrastructure. Furthermore, photographs were taken of the posters after every round to save all results.

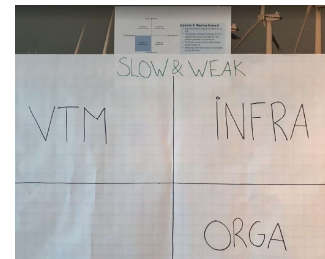


Figure E.1: Poster of scenario 3

E.6. REFLECTION ON THE BRAINSTORM-WORKSHOP

On forehand, the aim of the workshop was clear and the expected and desired results as well. The workshop gave insight in many problems, opportunities and chances for actions, which is really helpful for establishing the strategy roadmap. In addition, the composition of groups and the strategic mindset of participants led to different views on the scenarios which resulted in a diversity of problems and strategic actions. Afterwards, all participants mentioned they found the workshop well organised and the set-up clear and structured.

However, due to their strategic mindset, the participants found it difficult to think of concrete actions that can be taken in the future. They rather start now with long-term actions like ‘lobbying for the application of autonomous vessels’, ‘development of new business-models’ and ‘gain more knowledge about data’, instead of concrete actions like ‘create a autonomous vessel lobby team’, ‘make a new software program for faster clearances’ or ‘establish a dedicated data team’. This led to 80% of the actions had to be executed in the time-range 2019 till 2025. It might be interesting to include other, operational participants, in such a brainstorm-workshop as well. Also the duration of the workshop could be optimised. Even though the workshop was planned 1.5 month in advance, all four participants were only available for two and a half hours at the same time. This led to a brainstorm of fifteen minutes each round per scenario in total and not all participants have brainstormed about all scenarios. When more time is available more diverse problems and actions can be identified, which may contribute to a more resilient strategy.

Furthermore, a higher amount of participants will contribute to generation of more actions. For a brainstorm-workshop with four scenarios, eight participants available for a duration of circa four hours would be perfect.

In that case each round could last one hour, and participants could change scenario every fifteen minutes. On the other side, the small amount of participants made it easy for the facilitator to encourage everybody in their brainstorm and to assure everybody gave input in the sessions

The 'Resilient port-call-process 2050' workshop was organised and facilitated by the researcher. When processing the results from the brainstorm session, some actions and problems were not that clear since the context was missing. Therefore the participants were asked to clarify some of the actions they created afterwards. Even though tools and tricks found in literature were used, it is recommended to have a more experienced facilitator leading the session. This will offer the possibility to the researcher to actively listen to the brainstorm sessions and start with processing the results during the session. Undefined descriptions can then be clarified during the session.



(a) Pieter and Raymond



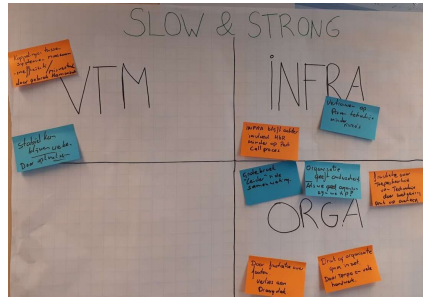
(b) Harmen and Cees

E.7. RESULTS OF THE WORKSHOP

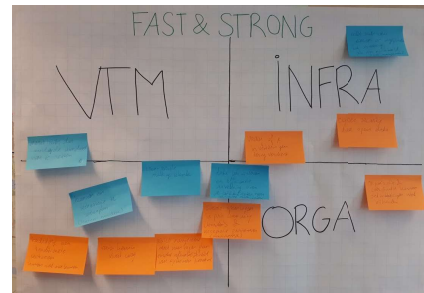
This section shows all results of the workshop before they are processed.

E.7.1. ROUND 1: PROBLEMS AND OPPORTUNITIES

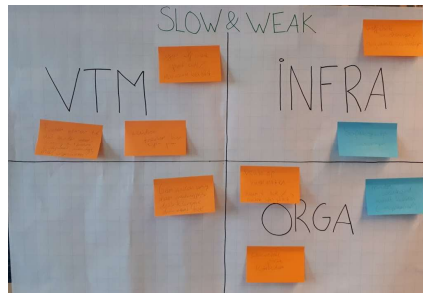
The participants were asked to project themselves in a scenario and brainstorm about potential problems and opportunities in the port-call-process. They had to write down at least 5 problems in 5 words. The participants had to assign the post-its to one of the cells on the poster of the corresponding scenario. The posters of the first round can be found in Figure E.3.



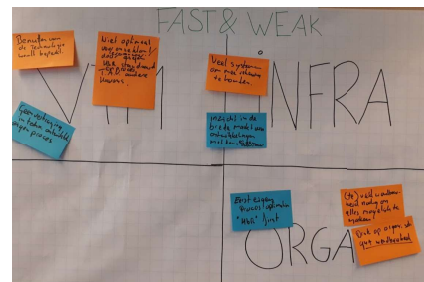
(a) Scenario 1: Reaching the limit



(b) Scenario 2: All hands on deck



(c) Scenario 3: Rippling forward



(d) Scenario 4: Rock the boat

Figure E.3: Posters after Round 1

In total, thirty-four problems and seventeen opportunities were identified. Some of the post-its, contained more than one problem. These have been split up. Most problems have been identified in Scenario 3: Rippling forward (weak collaboration and slow development). According to the participants most problems might occur in Vessel Traffic Management and within the organisation of the Harbourmaster. This might give an indication in the perceived level of agility of the Harbourmaster. If the Harbourmaster's organisation would have been perceived as being flexible and adaptable, the chance problems would occur due to changes in its environment would be less. Most opportunities were found in the scenarios with a strong collaboration.

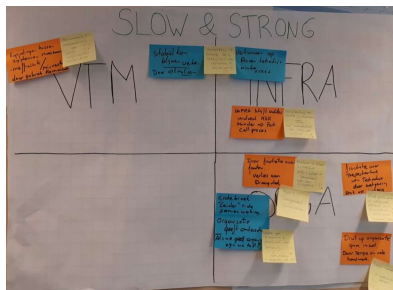
The problems and opportunities presented in table 7.2 are briefly explained:

- **System harmonisation.** Problems aimed on system harmonisation focus on the software, processes and (IT)-infrastructure all organisations in the port-call-process use. Since every organisation currently has there own processes and procedures, no general system is available. This leads to inefficiency, mistakes potential misunderstandings and frustrations about technology application.
- **Loss of support, pressure on the organisation/Harbourmaster, tempo growth too high focus on the role and capabilities of the Harbourmaster's organisation.** These problems are identified in multiple scenarios and might give an impression on the perceived agility of the Harbourmaster to anticipate to a changing environment.
- **Cyber risk.** Problems concerning cyber risks and IT dependence are identified in the 'all hands on deck' scenario and focus on the increasing role of technology in the environment of the Harbourmaster.

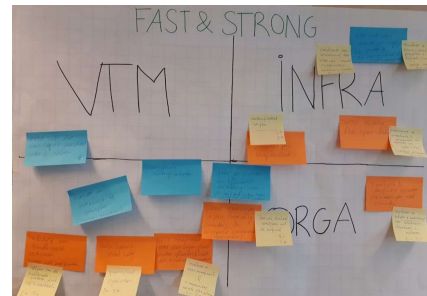
- Pilots draw own plan addresses the potential occurrence of the pilots that do not trust the Harbourmaster and are not willing to cooperate. They want to stay independent from the Harbourmaster.
- Traditional sectors cannot keep up, no increase in sustainability, societal and European pressure, high employment rate, less resistance labour unions are 'secondary' problems and opportunities, that result from the combinations of critical uncertainties in the operations in the port-call-process.

E.7.2. ROUND 2: ACTION

The next round was about the identification of actions to avoid or to respond to the problems, and to seize the opportunities. Actions were written down on yellow post-its and pasted on to the corresponding problem or opportunity. The results are shown in figure E.4. All actions are listed in chapter 7, table 7.3.



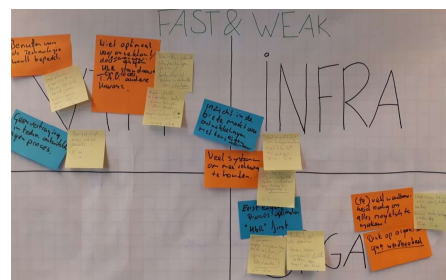
(a) Scenario 1: Reaching the limit



(b) Scenario 2: All hands on deck



(c) Scenario 3: Rippling forward



(d) Scenario 4: Rock the boat

Figure E.4: Posters with actions after Round 2

E.7.3. ROUND 3: RELEVANCE OF ACTIONS

In this round the actions are assessed based on their contribution to the long-term objectives: safety and efficiency. An example is illustrated in figure E.5.

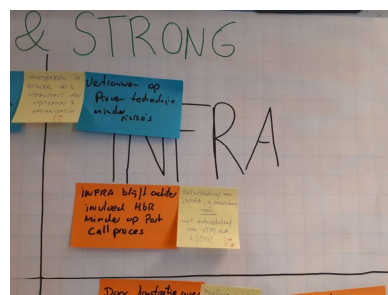


Figure E.5: Example of contribution of action to safety and efficiency

E.7.4. ROUND 4: SEQUENCE OF ACTIONS

In the fourth round, the actions designed in round two were assigned to a time-period. Participants were asked to replace the sticky notes from the scenario-posters to the timeline from the year 2019 to 2050. The results of this round give an indication for the pathways in the strategic roadmap. The introduction of the autonomous vessel is considered as an disruptive innovation and the estimation of its introduction is therefore marked on the timeline. The period of introduction of the autonomous vessel is based on the nearest (most extreme) point in future that is found in literature or expressed during interviews (see appendix C). Based on reports from the research institute Smartport, which is a consortium of the PoR, Deltalinqs, TNO, Deltaris, Erasmus Universiteit and Delft University of Technology, an estimation of the introduction of autonomous vessels has been made (SmartPort, 2018). They state fully autonomous ships will be operating within fifteen years from now. Since no earlier period of introduction of autonomous vessels has been found, the introduction of autonomous vessels has been presented on the timeline in the year 2035. The actions were sequenced on the timeline visualised in figure E.6 and listed in table 7.4.

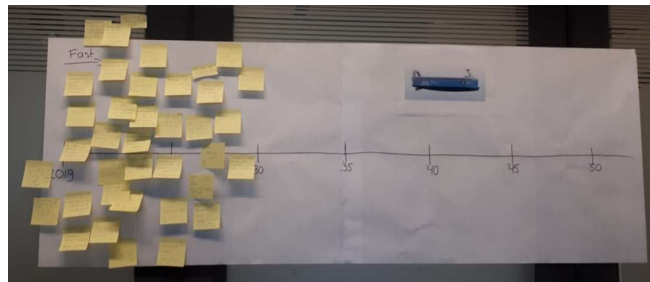


Figure E.6: Timeline

E.7.5. ROUND 5: PREFERENCE OF THE SCENARIOS

The last round was meant to identify the preferred scenario. A strategy is resilient if it is desirable by the organisation to implement (chapter 2, section 2.1.1). Therefore this round is essential. The preference of the scenarios was decided upon by voting.

The collaboration between organisations in the port-call-process was perceived as most important aspect having the most impact on the efficiency in the port-call-process. According to the participants, with a strong collaboration, both scenarios with a moderate applicability of technology as well as rapid applicability of technology could work. Therefore the preferred scenarios are Scenario 1 and Scenario 2. Everybody agreed that Scenario 3 is the least preferred scenario. Scenario 4 was considered a scenario where the Harbourmaster's role would be as a controller of the port-call-process.

E.7.6. AGGREGATION OF ACTIONS

Nine aggregated actions were developed. This section shortly elaborates on the aggregation of the qualitative actions.

1. Standardisation of data. Publish standards used by the Port of Rotterdam is a method to standardise the data. Therefore these two concepts have been combined. However, publish standard used by the PoR is already a specific action with the Harbourmaster as stakeholder. Therefore this action is used in the specification.
2. Invest in data and systems. This aggregated action comprises all concepts aimed on data and systems. However, the six concepts that are classified in this category have a diverse content which should be taken in to account in the specification of the aggregated actions.
3. Development of infrastructure. Conceptual actions in this category were all placed in the 'infrastructure-cell' in the workshop, and all focus on technologies in infrastructure. Again, some of the conceptual actions are already specific and might be relevant in the specification of actions.
4. Identify technical opportunities. Actions in this category are all aimed on experimenting, identifying

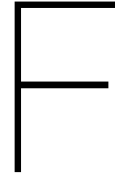
and seizing new technical opportunities to be used in the port-call-process, mainly in the management of vessel traffic.

5. Change management. All actions in this category were placed in the 'organisation-cell' and aimed on organisational support in a changing environment.
6. Stakeholder management. All actions in this category have in common that they are executed in collaboration with stakeholders. Therefore these actions cannot be implemented in the scenarios with a weak collaboration of stakeholders.
7. Control. All actions in this category imply a controlling role of the Harbourmaster by making use of his mandate to create rules.
8. Other. Conceptual actions in this category are diverse, general and therefore can be interpreted in various manners. This category has therefore not been taken into account in this research.

E.7.7. SPECIFICATION OF ACTIONS

This section elaborates on the reasoning behind the specification of actions based on the aggregated actions.

1. Standardisation of data has been specified to the former conceptual action 'publish standards used by the Port of Rotterdam'. This is a specific action with the Harbourmaster as initiator. At this moment Ben Scherpenzeel, director nautical developments, at the Harbourmaster's Department is initiator of the standardisation project.
2. Invest in data and systems is specified in to two concrete examples of actions. 'Create data, systems and security department' is a concrete action to implement the conceptual actions 'risk management' and 'invest in reducing cyber risk'. 'Investing in big data analysis and algorithms' combines all conceptual actions aimed on investing in current systems.
3. Development of infrastructure is specified in the two conceptual actions that satisfied the criteria for an action applicable in the resilient strategy roadmap. Invest in digital competencies and developing technology in collaboration with other ports both contribute to the development of infrastructure.
4. Identify technical opportunities is divided in two conceptual actions. 'Experiment with new technologies' covers the participation in the identification of technical opportunities, experiment with clients and technology firms. One of the ways to implement this action is to stimulate and facilitate start-ups and innovations. This action contributes to getting insight in the unused opportunities with respect to vessel traffic management.
Pressure on government for technology applicability is specified in the action lobby for applicability of new technologies.
5. Change management has been divided in two actions. One actions aimed on organisational change, covering actions aimed on organisational support (maintain acceptance, people management, stability of the organisation) and one action aimed on changes required in staff qualifications. The conceptual action 'adjust own strategy where needed' is relevant but too broad and can be interpreted in multiple manners.
6. Two actions are derived from the aggregated action 'stakeholder management'. Actively involvement of organisations in changes covers all conceptual actions focusing on support from the stakeholders. Discuss risks with stakeholders is focusing on risk management together with all organisations in the port-call-process and is derived from the conceptual action 'invest in risk management together with other organisations'.
7. Reduction on port tariff is a specific example action that is similar to the conceptual action. Enforce organisations to act upon the requirements of the Harbourmaster is covering the conceptual actions 'use authority to create rules', 'enforcement of organisations' and use 'authority as enabler'. Break monopoly of pilots is not been taken in to account since it has a negative impact on safety.



AUTONOMOUS VESSELS

Autonomous vessels (AVs) are expected to cause a major disruption on maritime operations in the port-call-process (SmartPort, 2018). Besides opportunities as improvement of efficiency, safety and sustainability, the development also brings challenges which need to be addressed.

In the analysis and design of resilient strategies, little attentions was paid to this development. Based on interviews and literature study, the researcher considers the introduction of AVs an important change in the current operations, this appendix serves as an extension of the main research and provides background information concerning autonomous vessels. Section F1 firstly elaborates on the phasing of autonomous vessels, next the impact on the current operations will be discussed, as an extension of section 5.3.2 in chapter 5.

F.1. PHASING OF AUTONOMOUS VESSELS

From literature is derived that the phasing of the introduction of autonomous vessels depends on the business-model, the technology, the port-infrastructure and the regulations. The business model contains all aspects relevant for the shipping companies and consignors; costs, time, efficiency and sustainability. This aspect is not discussed in this research since it is less important for the Harbourmaster. However, only if there is a business model concerning AVs, they will be introduced (Negenborn, 2018; Tabak, 2019).

TECHNOLOGY AND PORT-INFRASTRUCTURE

Devaraju et al. (2018) and Cappelle et al. (2018) describe the technology of autonomous vessels and port infrastructure needed to receive them. They state that to formulate AV scenarios not only AV applications and AV technology development need to be considered, but port infrastructure development and the phasing of the introduction of the vessels is important as well (Devaraju et al., 2018). Eleven scenarios have been identified based on the maturity of AV technology in ports. The maturity is measured based on the Technology Readiness Level as defined by NASA (Cappelle, 2017; Devaraju et al., 2018; SmartPort, 2018) (see figure F.1).

Devaraju et al conclude the first step towards autonomous vessels will be the placement of smart ship equipment in to existing vessels followed by remotely controlled vessels with reduced crews. A remote controlled vessel is a vessel defined by a person with the required qualifications who performs the navigation without being on board of the ship in person (Danish Maritime Authority, 2017).

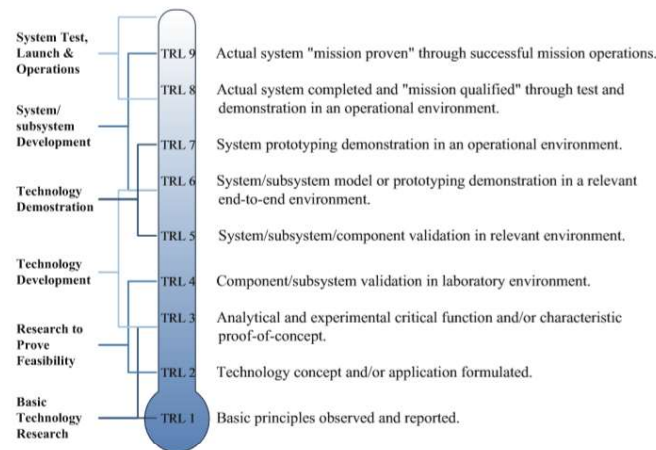


Figure F.1: Technology Readiness Level as defined by NASA (NASA, 2012)

The first applied areas will be short sea ships and inland shipping rather than deep sea shipping because of the possibility of shore-based sensors, size of the ships and legal aspects. The article leaves a gap on information towards autonomous vessels within a port environment. Schiaretti et al. (2017) and van Cappelle et al. (2018), discuss the phasing of autonomous vessels by means of four elements (see figure F.2):

- **Navigation:** Various sensors on a ship measure data about the surroundings of the vessel. By combining this data with a software-based sensor an image of the real world is created and send to the navigation subsystem of the smart ship.
- **Guidance:** This image is used by the guidance subsystem to chart the ship's route from origin to destination including nearby obstacles to avoid collisions.
- **Physical ship:** Additional hardware on the ship is required to support software-based decisions. New hardware can provide the same view and ability to act on information as the master of the ship now does.
- **Control:** The software-based control system converts the data provided by the path generation software into commands for various hardware to steer the ship in the right direction.

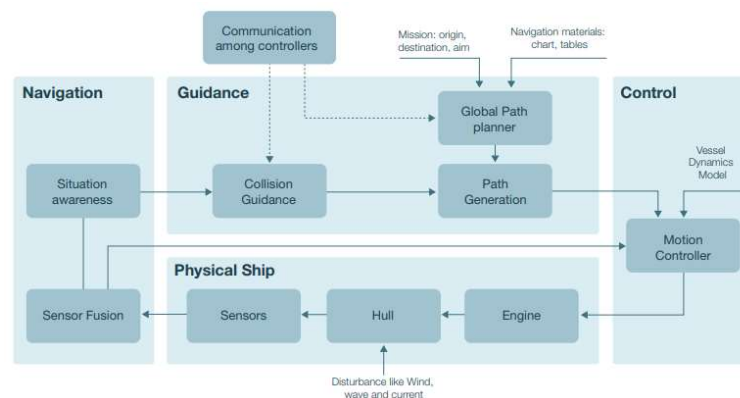


Figure F.2: Parts of an autonomous ship (SmartPort, 2018) & (Schiaretti & Chen, 2017)

Developments that are expected to become commercial on shorter term (in 5 to 10 years) are rated with TRL 7, 8 or 9 and are mainly basic sensors measuring obstacles, wind and depth. Both articles of van Cappelle et al. and Devaraju et al. mention the TRL of situation awareness and maintenance- and control- strategies

will take longest to be developed, especially for big ships as their reaction time is extremely long (Cappelle, 2017). Infrastructure wise, autonomous berthing is difficult to automate, but has a key role in reducing the crew on a ship. The same applies for maintenance, there is lack of good enough new manners to accomplish this autonomously. Devaraju discusses in his literature studies the infrastructural elements the Port of Rotterdam needs to adapt to accommodate AVs. Besides elements as improved internet, a shore control centre, autonomous tugboats and he also lays emphasis on the importance of an automatic mooring system.

Various initiatives (MUNIN, Yara Birkland, Robert Allan Ltd, JIP) currently experimenting with concepts for autonomous vessels. The main challenges these projects have to deal with lie in technical challenges of situation awareness, communication and cooperation and computational logistics technologies and control strategies. These are needed for safe operations, better scheduling and data-analysis (Devaraju et al., 2018). In order to meet the requirements for AV applications it is essential to upgrade port infrastructures, vessel assistance services and terminals. To meet these challenge, a trend towards autonomous vessels and port infrastructure has been framed which can be seen in figure E3

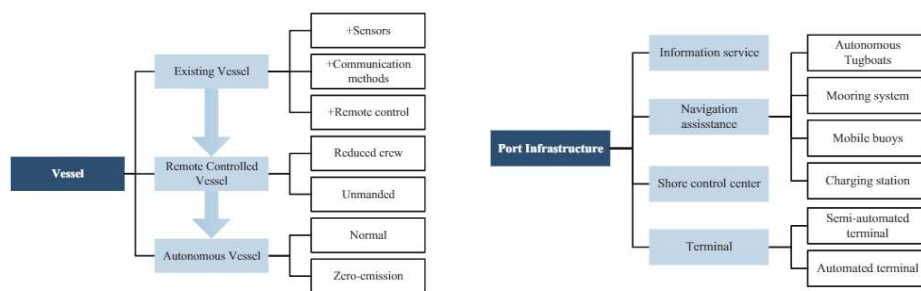


Figure E3: Development trends Autonomous Vessels and Port Infrastructure (Devaraju et al., 2018)

REGULATIONS

Besides the business model, technology and infrastructure, the Danish Maritime Authority mentions regulations as one of the key factors to the development of autonomous ships. Regulatory principles can be set up by the IMO, EU or nationally. The authors recommend that AVs are to the widest extent possible, regulated by the IMO to ensure that the vessel can operate in the largest area possible. To establish the regulatory approach for autonomous ships lessons can be learned from other autonomous means of transport such as cars, since some of the challenges will be the same (Danish Maritime Authority, 2017).

In case of autonomous vessels, new regulations are required concerning responsibility of the vessel. The traditional role of the vessel master will disappear and the associated legal duties will be divided to other actors (Chong, 2018). In addition, the interaction between the VTS operator and the Shore Control Centre requires new rules as well. Without such regulations related with safety of vessel traffic management, autonomous vessels cannot be introduced.

E2. IMPACT ON CURRENT OPERATIONS

The impact of autonomous vessels for the Harbourmaster lies in safety, efficiency and the changing role. It is crucial for autonomous shipping to be as safe as traditional shipping. A complex environment such as a port demands more on these fields from autonomous ships and infrastructure (SmartPort, 2018). Several researchers state that the most challenging period will be during the transition phase where autonomous ships will need to operate in mixed environments together with traditional ships, boats and infrastructure (Chong, 2018; Rylander & Man, 2016; SmartPort, 2018). A shore control centre and investments in infrastructure are mentioned as key considerations for successful and safe autonomous shipping.

Safety related, with improved sensor technology and ship-to-ship communication, incident prevention can be improved. This is also mentioned by Notteboom and Neyens (2017), where it is stated that human error is causing the majority of shipping accidents. Therefore by overcoming the named challenges effectively, maritime safety could be improved (Notteboom & Neyens, 2017).

Furthermore, Smartport acknowledges clarification of the roles of the Port Authority (PA) and Harbour Master and a continuous process of risk assessment as pre-conditions for autonomous operations. In addition, change of contracts, regulations and the human factor can be difficulties too in the journey towards autonomy (SmartPort, 2018).

The impact of autonomous vessels for the Harbourmaster has not yet been analysed in literature. However, for VTS, several sources provide information. The introduction of autonomous vessels will change the role and tasks of the VTS operators, especially in case Shore Control Centres are established.

- **Operations.** The absence of crew on an unmanned ship lead to challenges for VTS concerning the gathering of information, the assessment of the situation and the decision about what type of assistance is required (Chong, 2018). Physical (sight and hearing) and VHF communication between the vessel will be limited. This might result in inaccurate assessment of the emergency situation. A different skill is required from the VTS operator. They will need to be familiar with emergency and incident management procedures (IALA, 2016). In addition, information between the vessel or SCC, will be mainly available through digital format, which is heavily relying on data link and communication infrastructure available.
- **Technical.** The increase of reliance of software and digital information increase the need of ICT systems to interact with autonomous vessels. This brings the risk of an IT system being hacked. VTS will need a robust system and software to support the availability, reliability and security of communication (Chong, 2018).
- **Training.** Managing vessel traffic with AVs required new VTS operational procedures and systems. Adequate training is required for the VTS operators to be familiar with the operational risks and functions of the new systems. A certain amount of IT knowledge is required to understand the underlying principles of the operations of autonomous vessels (Chong, 2018).

CONCLUDING REMARKS

It can be concluded that autonomous ships will appear incrementally, which results in a period where unmanned or autonomous vessels operate together with traditional vessels. The application of different levels of autonomy depends on the complexity of the environment (congested traffic or dense surroundings). Where some research expects autonomous ships to be manned during passage in congested waters and approaching ports, other studies suggest the vessels to be unmanned and controlled remotely regardless of the complexity of the environment (MUNIN, 2016; Tvete, 2019). Nevertheless, expected is that ship owners would want to operate autonomously as long as possible to exploit the full advantage of autonomy and not involve additional costs (Chong, 2018).

An indication of the period of operation of autonomous vessel is provided in multiple studies. Expected is for remotely controlled unmanned ships to sail among traditional vessels in 2025 and a fully autonomous unmanned vessel is envisaged to sail by 2035 (MUNIN, 2016; SmartPort, 2018; Tvete, 2019)).

However, during interviews with experts in the field, the likeliness of AVs to be operating between 2025 and 2035 is small. To be operating as safe as traditional vessels, risks need to be mitigated which is challenging. Not only risks concerning safety of traffic, but also risks on cyber attacks or hijacking of the vessels and systems need to be taken in to account (Neef, 2018; Negenborn, 2018; Tabak, 2019). To cover the risks related to safety, an enormous amount of sensors is required as well as four backup systems in case of breakdown. This negatively influences the business model.

For the Harbourmaster to stimulate autonomous vessels, it is recommended to participate in and facilitate experiments and research related with AVs. Infrastructure required are autonomous berthing facilities, shore control sensor, faster internet and more advanced AIS stations and sensors. Expected is the traditional roles for organisations in the port-call-process change. Even though little research has been done in this field, several sources state that additional (IT-related) skills of the operators are required.