Future Scenarios: Implications for Port Planning

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Abstract

The evolving function of a port, and the many logistical, technological and economic uncertainties under which it must operate, make the planning and design of these complex socio-technical infrastructures very challenging. A Master Plan of a port is the instrument by which the port’s (expansion) strategy in the marketplace is defined. Therefore, a Port Master Plan needs to be dynamic and responsive to all external developments during its lifetime. The existing Master Planning approach is static and as a result it is poorly equipped to deal with the many uncertainties in the port and shipping industry. A new approach is required. The paper proposes an adaptive approach to planning that combines elements of Assumption-Based Planning (ABP), developed in the early 1990’s, and Adaptive Policy Making (APM) developed in 2001. It identifies in a structured way, the uncertainty in an existing plan, and subsequently improves its robustness and adaptability, through taking actions, either in the planning stage, or by preparing actions in advance that can be taken if an uncertain future materializes. The paper illustrates this approach by applying it to the current plan for Maasvlakte 2, the ongoing port expansion of Rotterdam in the Netherlands. The value of this proactive and dynamic approach lies in its manner of dealing with uncertainties. It leads planners to recognize vulnerabilities in a plan and incorporate strategies for dealing with them, adapting to new developments and building in capacity for taking advantage of new opportunities. The objective of using this adaptive approach is to realize a Master Plan robust across many futures, so that the port can meet the requirements of its stakeholders during its entire lifetime. This paper presents the first step in an ongoing research project sponsored by Port Authority of Rotterdam towards this objective.

1. Introduction

In the last 50 years, ports have evolved from being cargo loading/unloading locations to being crucial hubs in value-driven logistic-chain systems. They are now international logistic platforms acting as interfaces between production and consumption centers (Van de Voorde and Winkelmans, 2002). A new philosophy is emerging from these developments. A port is no longer a set of infrastructures and territory, but is recognized as a complex set of functions that, while interacting with the life of the local community, is interwoven with national and international interests, not only with regard to traffic and trade relations, but also in terms of organization and financial matters (Moglia and Sanguineri, 2003).

The port and shipping sector deal with the volatile world market and are thus much more affected by political factors, international trade, and overall world economic conditions than other enterprises. The shifting function of a port, as well as the many logistical, technological, and economic uncertainties under which a port must operate, make the planning and design of these complex socio-technical infrastructures very challenging. Port Master Planning plays a key role in determining a port’s position in the maritime hierarchy, not only because it identifies the port areas that need to be developed and defines their functions, but also because it is the instrument by which the port’s expansion strategy in the marketplace will be shaped (Frankel, 1989). In short, a Master Plan outlines the objectives of the port and how they are expected to be achieved.

Forecasting or anticipating demand is an essential element of Port Master Planning. The future is often seen as an extrapolation and multiplication of existing trends and technologies. The paradigm shifts brought by new technologies and new economic conditions are generally not considered, because they cannot be anticipated in full. This means that forecasts are generally more of a factor for the misallocation of resources than a sound planning tool. Long-term predictions either overestimate, underestimate, or completely miss the point, since they typically fail to capture paradigm shifts or structural shocks to the system (Notteboom and Rodrigue, 2008).

When structural shocks or unforeseen ‘wildcards’ present themselves – such as strikes, wars, a radical change of political power in a region, or a change of technology – they can upset the pattern either on a long-term or short-term basis. These wildcards are by nature volatile and when they have occurred in last few decades, very few organizations

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have anticipated such changes. However commercial success can be observed in those people or organizations who react quickly or positively to such changes and can see the potential advantages that might be offered (Alderton, 2004). It was through the recognition of future uncertainty and subsequent use of scenario planning to support decisionmaking and to develop suitable business tactics (at odds with the consensus opinions in the oil industry at that time) that Shell became so successful (Peterson, 2003).

However, discontinuity is not often addressed by organizations. An investigation carried out in scenario practice (van Notten 2005) included among others studies carried out by KPN Telecom, Port of Rotterdam (PoR), Central Planning Bureau (CPB), Foresight Futures, IPCC, KPMG, and ICL. These organizations assumed that they operated in a stable environment and that the driving forces were not powerful enough to cause a significant deviation from the current trends. Considering extreme scenarios was thought to be a redundant exercise and was a reflection of the negative connotation of discontinuity in the context of scenarios.

While there is broad agreement about the need to manage uncertainty within an ever changing context, few have suggested a framework for managing it or a set of tools to help cope with uncertainty. Recently, a new paradigm for the treatment of uncertainty has emerged. Instead of developing a static plan, this approach aims at developing plans that allow for change, learning, and adaptation over time based on new knowledge and changing circumstances. Assumption-Based Planning (ABP), initially developed by RAND in the 1990’s to solve a U.S. Army strategic planning problem, and since then applied to many projects, is a post-planning tool that deals in a structured way with uncertainty, in an existing plan. Adaptive Policy Making (APM) is a structured, stepwise approach developed only recently (Walker et al., 2001). The essence of an adaptive planning approach can be stated in two words: flexible and dynamic (RAND, 1997). It recognizes, that in an uncertain environment, planning is not a once for all exercise, but is a continuous iterative process to anticipate new developments. It leads the planners to recognize risks and incorporate strategies for dealing with them in the plan, as well as building in capacity for taking advantage of opportunities as they arise.

The paper will explain the fundamental principles of ABP and APM, and illustrate them through use of a post planning case study to make an existing plan robust and adaptable in the face of uncertainty.

Many of the terms used in this paper mean different things to researchers with different backgrounds. For the purpose of this paper, a plan is any type of action directed towards the future or a tentative solution to the exact problems posed by an uncertain future. Plan here refers to a Port Master Plan. Uncertainties are things that are not known, or known only imprecisely. Some uncertainties have no probability attached to it. However risk, which is one type of uncertainty, can be described in statistical terms. Risk is a measure of the extent of the loss from the failure of a planning assumption. Reducing risks is one of the major aims of APM.

A discontinuity, black swan, or wild card is a low-probability high-impact event, temporary or permanent, usually unexpected, that results in a break in a dominant condition in society (sometimes referred to as a structural change or paradigm shift). Flexibility in a plan enables it to be useful as requirements change. An adaptable plan has the capability to change over time in response to changing requirements. A robust plan is a plan that performs well in a variety of situations.

The paper is structured as follows. Section 2 describes the traditional approach to Port Master Planning and its limitations. Section 3 describes the principles of Assumption-Based Planning and Adaptive Policy Making, and proposes an adaptive approach that combines elements from both these approaches. In Section 5, this adaptive approach is applied to a case study of the PoR, the background of which is dealt with in Section 4. Section 6 presents the Adaptive Master Plan of the port expansion of Rotterdam. In Section 7, conclusions based on the paper are drawn.

2. Port Master Planning

2.1. Nature of Port Master Planning

The basic function of a port is to provide facilities to receive/dispatch and handle efficiently the projected cargo from/to the vessels of different sizes that will be calling at the port in the future (in addition to the industrial, logistic, and distribution functions that generate the value added, and are equally important for the port). A port needs to have a Master Plan, a blueprint for future development, reserving space where it may be needed in the future while taking account the regulatory, social, and environmental requirements, and the infrastructural system for economic port operation.

The elements of a Master Plan include the physical infrastructure, such as access channel, breakwaters and shore protection works, port entrance, turning areas, anchorage areas, inner channels and basins, quay walls, jetties and finger piers, rail connections, marshalling yards, connections between hinterlands and port, access roads, tunnels, bridges, locks, parking area and gate. This physical infrastructure, in combination with the superstructure, handling and transport equipment, operating procedures, management practices and development policies, facilitate the functions of the port.
Normally, a Master Plan is developed for a time horizon of 15-20 years. The Master Plan needs regular reviewing and updating. However, in most cases, the updating is mostly ad-hoc, and short-term measures are more often than not unrelated to the Master Plan. This does not mean that the Master Plan should not be made. It means that the Master Plan needs to be flexible to incorporate mid-course modifications in response to emerging situations and allow development in stages to follow fluctuations in economic development and changes in the transport patterns (Ligteringen, 2007).

By nature, port planning is a multi-disciplinary activity involving expertise in the fields of engineering, transport-economics, shipping, nautical matters, safety, and logistics. The port planners play a central role in the team, integrating the work done by these experts into a balanced design of the port lay-out.

However, the planning of a port is concerned not only with simply demand and supply of throughput, but with application of technology, marketing strategy and ultimately economic impact analysis for the development and implementation of a project (Gaur, 2005). This intricate and complex process can be seen in Figure 1, which shows the Port Master Planning process.

Figure 1 Port Master Planning process (Adapted from PoR)

2.2. Limitations of forecasting

Cargo forecasting in the Netherlands begins with Central Planning Bureau (CPB) scenarios that indicate the margins of economic growth in the Netherlands for the projection period, barring extreme conditions. These scenarios attempt to capture a reasonable bandwidth based on historical trends. However, while factors such as competitive environment of the port and potential trade shifts are considered, it is difficult to take into account future policies and technology trends. And, when periods of 20-25 years are considered, the estimation is likely to be far from accurate. In container transport, for instance, port development is very rapid and shipping lines tend to shift large volumes from one port to another. And on a global scale, as transport costs fall to extremely low levels, producers move from high-wage to low-wage countries, eventually causing wage levels in all countries to converge. These geographic shifts can occur quickly and suddenly, leaving long-standing port infrastructure underutilized or abandoned as economic activity moves on (Levinson, 2006).

Planners are increasingly relying on use of scenario analysis to produce forecasts of future environments, and for identifying key drivers leading to major changes in these environments. Yet, policymakers have a strong tendency to choose a single scenario or a single point forecast and use it for planning, rather than use different scenarios as a test of the robustness and flexibility of policy choices (Don, 2001). Furthermore, though low probability, high impact events that can change long established trends, are introduced in the scenarios to test the sensitivity of such analysis (Huss and Honton 1987), it is not often that attention is paid to developing strategies for reducing potential threats or taking advantage of the opportunities presented by these improbable occurrences.

2.3. Uncertainty in the container port sector: case studies

The essence of a Master Plan is that you should not do today what you will have to undo tomorrow. This section gives two examples of where this is exactly what happened, at a not inconsiderable expense.
Case 1 Nhava Sheva Port in Mumbai, India (Figure 2)

The Port of Nhava Sheva (or Jawaharlal Nehru Port) is India’s biggest port and handles almost half of the country’s maritime traffic (www.worldportsource.com). It was constructed in 1989/90, at about 20 kilometers from the existing overcrowded Mumbai port. The port, operated by Jawaharlal Nehru Port Trust (JNPT) handles 55 to 60 per cent of the total containerized import and export cargo of India.

The port originally had three operational terminals; two for containers and one for bulk cargo. In its second year of operation, the container throughput had increased from 33,880 to 54,643 TEU³ and the port authorities announced an extra investment in portal cranes and transtainers and an expansion of the container freight station.

However, the containerized cargo continued to grow at an exponential rate and in year 2004-2005, amounted to over 2.5 million TEU. In order to relieve congestion on the two container terminals, the Port Trust decided in 2006, to turn the bulk terminal into a container terminal. This terminal is now operated by Gateway Terminals India Pvt Ltd, a consortium of A.P. Moller-Maersk A/S Group and CONCOR, and has a capacity of 1.3 million TEU.

Since the container throughput is projected to grow considerably in the coming years, JNPT is ready with a feasibility study of a fourth container terminal with a 2,000 meter long container quay and a planned capacity of 4.5 million TEU.

Figure 2: Nhava Sheva Port, Mumbai, India

Case 2 Waalhaven in Rotterdam, the Netherlands (Figure 3)

In 2001, the biggest clients of container stevedores, Hanno en Uniport, China Shipping “K” Line, and Yang Ming, expressed the intention of putting in use, the new generation containerships⁴ of 5500 TEU at their terminals (at piers 5, 6, and 7) in the Waalhaven in PoR. At that time, only third or fourth generation ships, with a draft of about 11.0 meters, were being handled in Waal- Eemhaven. The Port of Rotterdam Authority decided to broaden and deepen the entrance to the Waalhaven port at a cost of 13.6 million euro, in order to receive these ships. This involved demolishing the sheds and their foundations, the existing quay walls and jetties, decontamination of the soil, and construction of a new quay wall at a distance of 78 meter behind the original wall, thus widening the entrance channel. In addition, the depth of new waterway was increased to NAP⁵-15.0 meter and the depth of Waalhaven basin from 13.50 meter to 14.5 meter, thus giving access to vessels with a draught of up to 14.0 meter (at high tide). The ships with a draught of 13.0 meter could enter the Waalhaven basin 20 hours per day, thus increasing the tidal current window significantly.

Hanno was taken over by ECT in 2004 to be used as overflow for the their home terminal in the Waalhaven and, barely five years later, the two terminals have been taken over by Steinweg, to be partially used for storage of empty containers. No 5500 TEU ships are expected to call at this terminal anymore.

This is a prime example of the uncertainty prevailing in the port sector!

Figure 3: Waalhaven entrance, Port of Rotterdam, The Netherlands

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³ TEU: Twenty-foot equivalent unit, 1 TEU is a container 20 feet long.
⁴ Currently, the size of the biggest existing vessel is approx. 13,500 TEU.
⁵ NAP is an abbreviation for Normaal Amsterdams Peil, and is a reference level for height-measurements in the Netherlands.
2.4. Why Master Planning fails

In both case studies, the Master Plan was based on specific assumptions about the future. The two major vulnerable assumptions were the container volumes to be handled at the ports and the size of future container ships. Unfortunately, the future that materialized was very different from what had been expected. Progressive global integration processes and trade liberalization, helped by remarkable developments in transport, logistics, and information and telecommunication technologies, had led to startling developments in the shipping industry. The rise of container shipping was changing the balance of world trade, rewriting the rules of modern manufacturing, and transforming port and manufacturing cities around the world (Zuckerman, 2007). The result was failure of the plans and a considerable loss of investments.

The existing Master Planning approach is a predict-and-act approach. It assumes that the future is known (and, therefore, the plan will work). The planners very often apply the strategy of anticipation, which involves an effort towards predicting and preventing potential dangers before damage is done. Trend-breaking developments are very hard or even impossible to anticipate, but should nonetheless be expected in complex and fast-evolving environments, and preparing for them constitutes an urgent challenge.

Also, the existing Master Planning approach is static and as a result poorly equipped to deal with the many future uncertainties in the port and shipping industry. A new approach is required.

3. Adaptive Planning

3.1. Description

Recently, a new paradigm for the treatment of uncertainty has emerged. Instead of developing a static plan, this approach aims at developing plans that allow for change, learning, and adaptation over time based on new knowledge and changing circumstances. Representatives of this paradigm are, for example, given by De Neufville (2000) and his Dynamic Strategic Planning approach, Walker et al. (2001) and Kwakkel et al. (2008) with their Adaptive Policy Making approach, and Burghouwt (2007) with his Flexible Strategic Planning. The method proposed here combines two methods, namely, Assumption-Based Planning (ABP), and Adaptive Policy making (APM).

The value of the proposed approach lies in its wholehearted acceptance of, and its manner of dealing with, uncertainty. Thus, the methodology is not so much concerned with the description of various futures or the likelihood of their materializing (since we have only a limited control over them, anyway), but with formulating strategies and actions aimed at minimizing the chance that the plan fails. This means that an understanding of the future changes in the world is more important than producing a plan.

The suggested approach helps to produce an adaptive plan by assuming that the future is unknown. The approach prepares to take actions to prevent a predict-and-act plan from failing. It is a structured way of dealing with uncertainty in an existing plan through being adaptable and flexible and building capacity to adapt to change. It aims to make the original plan effective across a variety of futures. Table 1 gives a comparison of the traditional and adaptive approaches as to planning.

<table>
<thead>
<tr>
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<th>Traditional approach to Master Planning</th>
<th>Adaptive planning approach</th>
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<tbody>
<tr>
<td>Treatment of the future</td>
<td>Assumes it is useful and possible to predict the future</td>
<td>Assumes that the future cannot be predicted, or it is dangerous to do so</td>
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<tr>
<td>Treatment of uncertainties</td>
<td>Uncertainty is included in the scenarios, but planning is eventually based on single point forecasts</td>
<td>Imagines Black Swans and prepares for them</td>
</tr>
<tr>
<td>Planning process</td>
<td>Static or at most periodic</td>
<td>Dynamic and continuous</td>
</tr>
<tr>
<td>Focus</td>
<td>On demand forecasts</td>
<td>On vulnerabilities and opportunities</td>
</tr>
<tr>
<td>Approach</td>
<td>Target oriented</td>
<td>Performance oriented (thus, flexible and integrated)</td>
</tr>
<tr>
<td>Reactivity</td>
<td>Ad hoc reaction to strong signals (certain knowledge about the future)</td>
<td>Monitors and reacts to predefined triggers (mostly performance indicators)</td>
</tr>
<tr>
<td>Decision-making</td>
<td>Decisions are based on available information</td>
<td>Regular acquisition of new information and evaluating potential developments as a way to</td>
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6 The Black Swan theory (Taleb, 2007) refers to a large-impact, hard-to-predict, and rare event beyond the realm of normal expectations.
3.2. Definitions

The proposed adaptive approach for port planning consists of five steps, the first two steps of which are from Assumption-Based Planning and the last three steps from Adaptive Policy Making. Though both approaches begin with looking for weaknesses in the plan, the terminology used is slightly different. ABP talks about assumptions underlying a plan.

- An assumption is an assertion about some characteristic of the world that underlies the current plan.
- A critical (load-bearing) assumption is an assumption whose failure would mean that the plan would not meet its objectives (i.e., would not be successful). An assumption is vulnerable if plausible events could cause it to fail within the expected lifetime of the plan.
- Risk associated with an assumption can be defined as the product of how serious the loss would be if the assumption failed and how likely it is to fail within the time horizon of the plan. Assumptions can be ranked in importance according to their risk.

APM uses the terms vulnerabilities and opportunities. These are developments that could influence the assumptions underlying the plan.

- Vulnerabilities are possible developments that can degrade the performance of a plan so that it is no longer successful.
- Opportunities are developments that can increase the success of the plan.

Having defined them, we will use these terms from now on.

3.3. Steps in Adaptive Planning

The various steps to be followed in the proposed approach for port planning are illustrated in Figure 4 and explained below. More details about ABP can be found in Dewar et al. (1993) and Dewar (2002), and about APM in Kwakkel et al. (2008).

**Step I  Examining the existing plan and identifying underlying assumptions**

This first step involves studying the existing plan in order to identify the objectives of the organization, the definition of success of the plan, the various constraints or boundary conditions, the available options, and of course the underlying assumptions. Based on this, the definition of success can be given, in terms of the specification of desired outcomes. This is required in order to be able to decide when the plan needs to be changed.

**Step II  Identification of the load-bearing and vulnerable assumptions**

In Step II, the load-bearing and vulnerable assumptions in the plan are identified. Identification of load-bearing assumptions requires an assessment of the consequences of failure of an assumption. Identification of vulnerable assumptions involves thinking about the future, for plausible developments that could occur in the lifetime of a plan and cause the plan to fail. If the development causes the plan to fail in its favour, it is called an opportunity. Otherwise, the development is called a vulnerability. These vulnerabilities and opportunities are dealt with in subsequent steps.

Dewar (2002) describes various techniques for carrying out Steps I and II.

**Step III  Increasing the robustness of the basic plan**

In the third step of the process, the robustness of the plan is increased. This step is based on specifying actions to be taken in response to the vulnerabilities and opportunities identified in Step II. There are two basic ways of preparing a plan for vulnerabilities and opportunities, either by taking actions now, or by preparing actions in advance that can be taken in the future if necessary (the latter is considered in Step IV).

There are four different types of actions that can be taken in advance in anticipation of specified contingencies or expected effects of the plan in order to make it more robust:

- a shaping action is an action taken now that is intended to affect the vulnerability of a critical assumption, either by reducing it or changing its nature;
- a **mitigating action** is an action taken now to reduce the certain adverse effects of a plan;
- a **hedging action** is an action to spread or reduce the risk of uncertain adverse effects of a plan, and
- a **seizing action** is taken to seize available opportunities that are certain.

Mitigating actions and hedging actions prepare the basic plan for potential adverse effects and in this way try to make the plan more robust. Seizing actions are actions taken now to change the plan in order to seize available opportunities. In contrast, shaping actions are pro-active and aim at affecting external forces in order to reduce the chances of negative outcomes or to increase the chances of positive outcomes.

**Step IV  Contingency planning**

Even with the actions taken in advance, there is still the need to monitor the performance of the plan and take action if some of the assumptions are failing. In the fourth step, the plan is further expanded via contingency planning, in which the plan is further enhanced by including adaptive elements. The first element of the contingency plan is the identification of signposts. Signposts specify information that should be tracked in order to determine whether the plan is on course to achieving its success. The starting point for the identification of signposts is the set of vulnerabilities and opportunities specified in Step III. Critical values of signpost variables (triggers) are specified, beyond which actions should be taken to ensure that a plan keeps moving the system in the right direction and at a proper speed. These actions
are prepared for in advance; most represent changes to the basic plan. We can define four different types of actions that can be triggered by a signpost:

- **defensive actions (DA)** are actions taken *after the fact* to clarify the plan, preserve its benefits, or meet outside challenges in response to specific triggers that leave the basic plan unchanged;

- **corrective actions (CR)** are adjustments to the basic plan in response to specific triggers;

- **capitalizing actions (CP)** are actions taken *after the fact* to take advantage of opportunities that further improve the performance of the plan, and

- **reassessment (RE)** is a process to be initiated or restarted when the analysis and assumptions critical to the plan’s success have clearly lost validity.

**Step V Implementation**

Once the basic plan and additional actions are agreed upon, the final step involves implementing the entire plan. In this step, the actions to be taken immediately (from Step III) are implemented and a monitoring system (from Step IV) is established. After implementation of the initial mitigating, hedging, seizing, and shaping actions to make the plan robust, the adaptive planning process is suspended until a trigger event occurs. As long as the original plan objectives and constraints remain in place, the responses to a trigger event have a defensive or corrective character - that is, they are adjustments to the basic plan that preserve its benefits or meet outside challenges. Sometimes, opportunities are identified by the monitoring system, triggering the implementation of capitalizing actions. Under some circumstances, neither defensive nor corrective actions might be sufficient to save the plan. In that case, the entire plan might have to be reassessed and substantially changed or even abandoned. If so, however, the next plan deliberations would benefit from the previous experiences.

This method will be applied to the case of port expansion in Rotterdam in Section 5. Section 4 gives a concise background of the project Maasvlakte 2.

**4. Case study**

**4.1. Introduction**

This section describes the project Maasvlakte 2, discusses briefly the approach followed for Master Planning, and describes various measures devised for dealing with uncertain developments.

**4.2. Project Maasvlakte 2**

The port of Rotterdam, the largest port in Europe and the world's sixth-largest container port, has almost reached its limits in terms of space. In the existing port and industrial area, there is hardly any room left for new companies and existing clients wishing to expand. The Maasvlakte 2 project, an expansion of the existing PoR into the North Sea, is a venture of the Port of Rotterdam Authority. The planning for the project was started in 1993, the land reclamation began in September 2008, and the first ship will be received in 2013. The construction will be carried out in phases, and it is only in 2033 that Maasvlakte 2 will be fully operational.

**4.3. The Master Plan and Business Case**

The Master Plan of Maasvlakte 2 (Rotterdam Mainport Development Project (PMR), 2008) has been drawn up on the basis of several assumptions, the most important of course being the projected port traffic and throughput volumes, which are determined by continually varying factors such as market forecasts, client demands, governmental policies as well as various technical, environmental, economic, financial, and social factors. The Master Plan seeks to allocate the land within the port to the various uses required, aiming at an optimized layout of the port and the port-land interface. Progressive insights as a result of the numerous research studies, regular updating of the market forecasts, input from the contractors and the future clients, have all led to revisions in the Master Plan, which is now in its fourth version. It has a central role in the project and forms the basis for tendering and execution of the construction work, taking care of the necessary procedural preparations, marketing Maasvlakte 2 in order to attract clients, in order to assure sufficient return on investments.

The Maasvlakte 2 project is a business case directed project. The business case forms, at every stage, the basis for determining the profitability of the project. If the realization of the desired profit is in danger, changes can be made in advance. Directing the project by means of the business case study prevents the creation of sites that would later prove unprofitable. The major elements of this business case are: investments, costs or expenditures, and income or revenue. The Master Plan forms the basis for determining the investment at any stage of the project. The harbour dues, rental fees, and quay dues are the revenue sources for the Port Authority, while the operational costs are the overhead, maintenance costs, nautical services, and working capital. The Master Plan gets more detailed in every cycle as more
information becomes available and the business case gets more real. The business case and the Master Plan are closely related and provide managers with the support they need to program the implementation of the overall strategic plan (Rotterdam Mainport Development Project (PMR), 2008).

### 4.4. Objectives

The overall objective of the expansion of the port of Rotterdam through construction of Maasvlakte 2 is to reinforce the international competitive position of the port and industrial complex (and thereby help strengthen the economic structure of the city and region, thus contributing to the Dutch economy as a whole and contributing to a better residential and living environment in the region). With a total maritime container throughput of 40.1 million TEU in 2008 handled along a shoreline of 500 nautical miles, the Hamburg-Le Havre range (including ports such as Rotterdam, Hamburg, Antwerp, Bremerhaven, Le Havre, Zeebrugge, Amsterdam and Dunkirk) ranks among the busiest and most competitive container ranges in the world (Wiegmans et al., 2008).

Besides the Port Authority, the port has other stakeholders, including the terminal operators and/or shipping lines, shippers, trucks and barge operators and of course the whole community that is affected by the construction of an intermodal terminal. The stakeholders have varied, and sometimes, conflicting objectives. Whereas the port authority and terminal operators are concerned mainly with the financial viability of the terminal, terminal operators also demand flexible space, adequate capacity of waterways, low operating and maintenance costs, reliable handling equipment, good rail and road access, and low land lease rates. The shipping lines demand fast vessel turnaround time, good berthing facilities, around the clock service, and low total costs.

The objective of the Port Authority can be stated as follows:

To attract cargo flows for the deep sea-related container sector, the chemical industry and the distribution parks, by creating sufficient extra space, in a sustainable manner, directly on the North Sea, while providing high-quality service by handling cargo efficiently and maintaining standards of safety, cleanliness, and security.

### 4.5. Dealing with uncertainty

Flexibility has been a major goal in the port’s Master Planning, the motto being *Create your own future* - that is, maximum flexibility for the client in the planning of his terminal on Maasvlakte 2. The design & construction contract with the building consortium PUMA (contracting firms Boskalis and Van Oord) gives it an enormous amount of freedom in how it carries out the project. As long as it satisfies the *schedule of requirements*, improvement in the design can be carried out after the contract had been signed. Moreover, flexibility in time is achieved by adapting the development of Maasvlakte 2 to the actual market demand, and phasing the implementation of plans.

At the time the present Maasvlakte was conceived, no one had an idea about how it would develop in the future, and transport via containers was not in the picture. During Master Planning for Maasvlakte 2, however, awareness of the uncertainties led to use of techniques such as scenario building, uncertainty and risk analysis (Rahman et al., 1999), trend break analysis (Walker, 1997), and computer-supported simulation gaming (Bekebrede and Mayer, 2006). These were used to gain insights into future developments and to anticipate the uncertainties associated with these developments. This strategy of anticipation involves an effort towards preventing negative outcomes and can be effective in coping with known threats and problems, but becomes ineffective when uncertainty, dynamics, and volatility increase (Wildavsky 1991). Under circumstances of deep uncertainty and large risks, robustness can be a successful management and decision strategy. One way to design a robust plan is to make it flexible, so it can adapt to the changing conditions under which a port must operate. This approach, called ‘planned adaptation’, allows implementation of the plan to begin prior to the resolution of all the major uncertainties. Over time, when new information becomes available, the plan can be adapted to meet the new conditions.

Such an approach will be illustrated by applying it to the case study in the next section.

### 5. Adaptive Planning applied to the Port expansion of Rotterdam

#### 5.1. Introduction

In this section, we will illustrate how the proposed adaptive planning approach might be applied to the case study of the port expansion in Rotterdam, introduced in the previous section. Many of the challenges and the solutions have been oversimplified in this case, in order to make the planned adaptation approach clear and understandable. Each of the five steps of the adaptive planning approach, discussed in Section 3, is now applied to the case study.

- In Step 1, we define what constitutes the Master Plan of the port expansion, the major constraints and boundary conditions to be kept in mind while applying the adaptive approach, the objective of the plan, and the definition of success.
Next, we describe a brainstorm session organized at the PoR, to discuss the developments or the driving forces in the external environment that can adversely affect the plan by undermining certain assumptions during the lifetime of the project. This exercise helped to identify the load-bearing and vulnerable assumptions in the plan, and constitutes Step II of the adaptive planning approach.

- In Step III, we define actions that can be taken in the planning phase to make the plan robust.
- Step IV involves implementing a monitoring system and the start of collection of signpost data. It also identifies future actions that can be triggered by the signposts, which can serve to protect the plan.
- In Step V, the actions triggered by the signposts are taken.

5.2. Step I Examining the existing Master Plan and identifying underlying assumptions

The Master Plan for Maasvlakte 2 (version 3.2) is illustrated in Figure 5. It shows the end situation in 2033, whereby 625 ha of space is reserved for container terminals, 210 ha for the chemical sector, and 165 ha for the distribution sector. Before the actual construction work began, 40% of Maasvlakte 2 was leased for container handling to the companies APMT, Rotterdam World Gateway, and Euromax.

The location of the port expansion, the form of the external contour of the reclamation-area, the port entrance, and the orientation of the port basins, have all been determined after careful study. The two port basins are intended for establishment of container terminals on either side. The west side of the Yangtzehaven is connected to the basin on the east side with a channel, on either sides of which turning areas for the ships have been created.

The Master Plan, for the purpose of our study, comprises:
- the port layout and detailed drawings;
- associated documents, such as the zoning plan, the PKB (Key Planning Decision), various permits and technical standards;
- the Maasvlakte 2 business case and contracts with investors, clients, and contractors.

When applying adaptive planning to the Master Plan, a major constraint is that there is no possibility for drastic adaptations in the first phase of the Master Plan whereas the following phases give reasonable room to do so. (Although the Master Plan itself may not be adapted in phase I, ABP and APM use shaping actions to deal with uncertainty through reducing the vulnerability or altering the nature of the critical assumptions).

**Definition of Success**

The objective of the Port Authority (with the port expansion) can be stated as follows:
to attract cargo flows for the deep sea-related container sector, the chemical industry and the distribution parks, by creating sufficient extra space, in a sustainable manner, directly on the North Sea, while providing high-quality service by handling cargo efficiently and maintaining standards of safety, cleanliness, and security.

This objective could be met if the port development (supply) can be coordinated with the market demand for the three market sectors (the deep sea-related container sector, the chemical industry, and distribution). This would be indicative of a viable business case, implying a safe return on investments for the investors. (To be more specific, the Port Authority has assumed in its business case an internal rate of return of at least 8.55% on their investment and a total cost of 2.9 billion euros; this amount represents the investment including contingencies for a price index based on 2006). Success of the business case (which is integrated with the Master Plan) is based on its assumptions on both the supply and demand side remaining valid, and uncertainties, if and when they manifest themselves, being adequately dealt with.

**Major assumptions**

Many of the assumptions are related to the current state-of-the-art technology and the existing policies.

The major assumptions in the Master Plan are related to:

- the vessel sizes;
- the choice of cargo sectors to be handled at Maasvlakte 2;
- the timing and volumes of market demand in the chosen market sectors (the deep sea-related container sector, the chemical industry, and distribution);
- the modal shift or the distribution of the hinterland cargo over the three modalities, road, rail and inland shipping;
- cargo handling concept (equipment and operations) at the quay;
- cargo handling concept (equipment and operations) in the yard or stacking area;
- user requirements (e.g. multi-user or dedicated terminal, shared or individual rail and barge service centers, sharing of equipment or not, value added activities or not), and
- the existing policies/ regulations with regard to standards of security and sustainability (which include, among others, the issues of nautical safety, port accessibility, emissions and noise pollution).

### 5.3. Step II Identifying load-bearing or critical assumptions

As an aid towards identifying load-bearing, vulnerable assumptions in the existing Master Plan and subsequently improving its robustness and adaptability in the face of uncertainty, a brainstorm session was organized at the PoR. The aim was of the session was to:

- obtain strategic insights into the major driving forces or developments in ports and the shipping industry;
- discuss the implications of these developments for Maasvlakte 2, and
- identify which of the developments could undermine the assumptions in the Master Plan for Maasvlakte 2.

The external developments that could undermine the assumptions in the Master Plan can be broadly listed under four categories: technology, market and economy, politics and legislation, and environment and society (Figure 6). These developments can influence the demand directly or undermine the other assumptions in the Master Plan.

Among others, the planners and decision makers from the PoR were invited to participate in the brainstorm session in order to construct relevant future scenarios and discuss plausible relevant developments. In addition to the experts, the participants also included generalists with a broad view. The session involved four steps.

1. The participants were asked to list on paper plausible future developments for each of the four categories listed above. These developments were not required to be limited to the port and shipping sector. The exact time
horizon was not defined; the participants were asked to think in the long term. No probability scale was predefined for the exercise; as a result trend break scenarios with low likelihood of occurrence as well as foreseeable trend developments appeared in the lists. (Trend scenarios assume that the future will, in all important aspects, be a continuation of the present and the recent past, while trend break scenarios allow for structural changes in the system.) The developments could be positive or negative; what often seems to be a negative development at first may later prove to be one of hidden opportunity.

2. These lists were then collected, and the large number of plausible developments was reduced to a manageable amount by sorting them into clusters. The developments that could be significant for Maasvlakte 2 were listed for each of the categories.

3. The participants were then requested to list the possible implications of these developments for the port and the port expansion. This could help in evaluating if a particular development could lead to the failure of the plan in its lifetime.

4. The list of impacts was further examined. The developments and the resulting vulnerabilities/opportunities, most likely to be significant for Maasvlakte 2, could subsequently be identified.

Table 2 gives a list of the major driving forces and the resulting vulnerabilities and opportunities, most likely to be significant for Maasvlakte 2, could subsequently be identified.

**Table 2: Some vulnerabilities, and their key driving forces**

<table>
<thead>
<tr>
<th>Major driving forces</th>
<th>Vulnerabilities and Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port expansion will lead to increased road transport and congestion on A15 highway, which is the major road linking the port to the hinterland</td>
<td>Reduction of the land side accessibility</td>
</tr>
<tr>
<td>- Depletion of fossil fuels</td>
<td>Increase in energy prices</td>
</tr>
<tr>
<td>- Changing pattern of supply and demand of energy (newly emerging economies)</td>
<td>Deterioration of city-port relationship</td>
</tr>
<tr>
<td>- Geopolitical tensions between energy-importing and energy-producing countries</td>
<td>Changing port competition due to growing risks and uncertainties</td>
</tr>
<tr>
<td>- Shift towards renewable energy sources such as bio-fuels, wind, solar and nuclear energy</td>
<td>Container demand grows faster than forecast</td>
</tr>
<tr>
<td>- Migration of activities to the west, far from the city</td>
<td>Container demand grows slower than forecast</td>
</tr>
<tr>
<td>- Demographic ageing</td>
<td></td>
</tr>
<tr>
<td>- No workers in the port</td>
<td></td>
</tr>
<tr>
<td>- Reduced tolerance for negative environmental impact</td>
<td></td>
</tr>
<tr>
<td>- PoR goes to the stock market</td>
<td></td>
</tr>
<tr>
<td>- Vertical and horizontal integration in supply chains</td>
<td></td>
</tr>
<tr>
<td>- Economy of scope as important as economy of scale</td>
<td></td>
</tr>
<tr>
<td>- Focus on reliability and capacity in addition to costs</td>
<td></td>
</tr>
<tr>
<td>- Discontinuous hinterland due to creation of transport corridors</td>
<td></td>
</tr>
<tr>
<td>- Increasing economic development leading to increasing consumption e.g. in eastern Europe</td>
<td></td>
</tr>
<tr>
<td>- Increasing globalization (diversified market, globally networked production, flexibility of production and labour processes)</td>
<td></td>
</tr>
<tr>
<td>- Shifting of location of production centers to the west due to instability of low cost economies and increasing transportation costs</td>
<td></td>
</tr>
<tr>
<td>- Change in consumption patterns and customer preferences</td>
<td></td>
</tr>
<tr>
<td>- Protectionist measures</td>
<td></td>
</tr>
<tr>
<td>- Environmental constraints for sea transport, e.g., stricter controls by International Maritime Organization (IMO) and mandatory 100 % container scanning lead to high costs</td>
<td></td>
</tr>
<tr>
<td>- Use of other trade routes, such as the silk route and Trans-Siberian railroad could mean loss of container traffic from the east</td>
<td></td>
</tr>
<tr>
<td>- EU requires equal distribution of containers for all ports in Hamburg-LeHavre range, thus no Mainports</td>
<td></td>
</tr>
<tr>
<td>- National legislation becomes stricter than European legislation, leading to unfair competition</td>
<td></td>
</tr>
</tbody>
</table>
Major driving forces

Utilization of economies of scale
- Innovation and new technologies in many disciplines makes design of mega ships feasible

Improved turnaround time for ships
- Innovation in equipment and transport
- Innovative handling concepts, direct transshipment to different modalities
- Improvement in communication and information technology (far reaching management and control of production and transport flows)

Increasing focus on sustainability will demand a shift towards an environmental friendly form of transport
- Internalization of costs makes road transport costly, and transport by inland ships competitive

Congestion on road and reduced port accessibility causes hazard for road safety
- Increase in shipping traffic proves hazardous for nautical safety
- Increasing dependence on technology results in increasing vulnerability
- Low emission quotas specified by EU are easily exceeded

Reduced container throughput
- No container handling permitted on Maasvlakte 2 due to negative environmental impact
- No road transport permitted from the port
- Activity/industry from Waal/Eemhaven area has to shift to Maasvlakte 2 to improve quality of the living environment
- Maasvlakte 2 must become ‘energy port’ for renewable energy as refineries and petrochemical industry disappears from the port
- PoR goes to the stock market and shareholders insist on space usage with high turnover
- European legislation takes market power from the port

Vulnerabilities and Opportunities

Mega ships appear

Increase in quay/ terminal productivity

Modal shift in favour of inland shipping

Non-compliance with standards of security and safety

Maasvlakte 2 must accommodate other cargo sectors/ activities

<table>
<thead>
<tr>
<th>Wildcards</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container is replaced by ‘mega-box’ to utilize economies of scale</td>
<td>New equipment, handling methods and transport logistics would require enormous investments</td>
</tr>
<tr>
<td>New generation containerships, smaller and faster, are designed to achieve greater flexibility</td>
<td>This would stimulate multi-porting instead of main-porting, and the resulting changes in distribution patterns would require new infrastructural investments</td>
</tr>
<tr>
<td>Seal level rises faster than expected</td>
<td>As temperatures and water levels rise, all efforts are geared to stopping further damage. Economy and trade suffer.</td>
</tr>
<tr>
<td>Global climate change leads to extreme weather conditions and large tides, making entrance of ships via Maasmond and Yangtzehaven impossible</td>
<td>Ships would choose to call on other ports.</td>
</tr>
<tr>
<td>Credit crisis</td>
<td>Access to credit is key to the survival of maritime trade and trade shrinks as the credit markets freeze.</td>
</tr>
<tr>
<td>Disruption of the information systems controlling port flow</td>
<td>Even a tiny disruption of port operations will affect the entire supply chain</td>
</tr>
<tr>
<td>Closure of choke points such as Suez canal, Panama canal or Strait of Malacca</td>
<td>Longer shipping routes will make sea-transport costly</td>
</tr>
<tr>
<td>Fossils fuels are exhausted</td>
<td>Trade and sea transport suffer due to political turmoil and</td>
</tr>
</tbody>
</table>
increasing transport costs; production is regionalized

| Terrorist attacks, cyber warfare, world conflict, return of communism | Such events could leave the world in a state of shock and disarray, and with a depressed economy |
| PoR is subject to far reaching European regulations | The competitive position of the port will be threatened |

5.4. Step III  Vulnerabilities and opportunities of the basic plan and anticipatory actions

As we have seen in Section 5.3, the development of Maasvlakte 2 is complicated by the many diverse trends and developments, which present both vulnerabilities and opportunities. Some of these developments are relatively certain and others are uncertain. The Port Authority can add shaping and mitigating or hedging actions to the current Master Plan. Shaping actions can include promotional or marketing campaigns, tariff regulating strategies, use of concessions and incentives, new collaborations, uncertainty absorbing contracts with the clients, restructuring of vertical relationships with contractors or customers, and instituting new market mechanisms such as bidding / auctioning systems. Mitigating and hedging actions aim at reducing certain and uncertain adverse effects of a plan; this can be achieved by physical alteration to the Master Plan, changes in manner of operation, or diversification.

Certain developments

Some examples of relatively certain future developments (see Table 4) are increase in energy prices\(^7\), reduction in landside accessibility, deterioration of port-city relationship (unless actions are taken), and the changing nature of port competition (due to changing function of ports). The actions, in response to these vulnerabilities are listed in Table 4, and are discussed further in Section 6.

Table 4: Some Certain Vulnerabilities, and Responses to Them

<table>
<thead>
<tr>
<th>Vulnerabilities and Opportunities</th>
<th>Mitigation (M), Shaping (SH), and Seizing Actions (SZ)</th>
</tr>
</thead>
</table>
| **Reduction of land side accessibility** | SH1: Invest in R&D into the landside accessibility in Rotterdam and neighboring area and new transport options  
SH2: Use price strategies, internalize external costs in pricing of road transport to stimulate transport by rail and inland ships  
M1: Invest in a network of container transferia, inland container depots (extended gates concept)  
M2: More TEU per truck, night shifts for trucks and improvement in cross border rail connections in Europe  
M3: Invest in infrastructure for inland ships  
M4: Invest in underground infrastructure |
| **Energy price rise in the long term** | SH3: Invest in R&D into cost-efficient and renewable sources of energy |
| **Deterioration of city-port relationship** | SH4: Improve living environment in the city  
SH5: Attract new activities and stimulate economic renewal in the city area  
SH6: Make the port attractive by stimulating recreational and multi-cultural activities |
| **Changing port competition** | SH7: Timely investment in infrastructure and hinterland connections, investment in R&D  
SH8: Offer integrated services and increased reliability and safety  
SH9: Diversify, also in non port related activities increasing the capacity to absorb losses and cross-subsidize within the port  
SH10: Assume role as facilitator in the supply chain |

Uncertain developments

Most of the identified developments are uncertain. The real challenge for the development of Maasvlakte 2 is presented by the uncertain vulnerabilities and opportunities. The timing and volume of demand, ships that will call at the port in the future, technological innovation leading to increased productivity, modal shift in favour of inland shipping, and non-compliance with standards of safety and security, are all vulnerabilities for the Master Plan. The vulnerability of other cargo sectors to be accommodated at Maasvlakte 2 than in the present Master Plan is treated further as a wildcard. Table 5 presents some of the hedging and shaping actions that can be taken now to handle these vulnerabilities. Further discussion follows in Section 6.

\(^7\) The tumult in price of crude oil from $145 per barrel in the summer of 2008 to $49 in 2009 is a contradiction to this trend.
Table 5: Some uncertain vulnerabilities, and responses to them

<table>
<thead>
<tr>
<th>Vulnerabilities and Opportunity</th>
<th>Hedging (H) and Shaping (SH) Actions</th>
</tr>
</thead>
</table>
| **Container demand grows faster than forecast** | SH11: Negotiate uncertainty absorbing contracts (additional income from the concessionaire)  
H1: Invest in modular, interoperable infrastructure  
H2: Adapt Master Plan (incorporate value of flexibility to generate a viable business case) |
| **Container demand grows slower than forecast** | SH12: Promotional or marketing activities by PoR as well as the terminal operator  
SH13: Negotiate uncertainty absorbing contracts (compensation by the concessionaire)  
H3: Invest in modular/ flexible infrastructure  
H4: Spread risk by diversification into:  
- other cargo  
- non-port-related functions, such as real estate |
| **Mega vessels appear (a)**  
Ships bigger than 12,500 TEU and smaller than 18,000 TEU  
(draught less than 17.4 meter; length more than 450 meter) | SH14: Competitive advantage for MV2, set up positive campaign, increase tariffs  
H5: Define new nautical rules, reduce ship speed in basins for certain wind conditions and passing ships  
H6: Reserve budget for dredging, bollards, fenders, bigger tugboats |
| **Mega vessels appear (b)**  
Ships bigger than 18,000 TEU  
(draught less than 17.4 meter; length more than 450 meter) | SH15: Set up negative campaign against mega ships, announce increased tariffs  
H7: Invest in R&D to study feasibility of ship size and nautical requirements  
H8: Re-evaluate Master Plan & redefine nautical rules  
H9: Invest in R&D to study implications and adapt Master Plan |
| **Increase in quay/ terminal productivity** | SH16: Negotiate uncertainty absorbing contract with operator  
SH17: Terminal operator must invest in improving hinterland connections  
SH18: Invest in R&D to study implications  
H10: Adapt Master Plan if possible and necessary |
| **Modal shift in favour of inland shipping** | SH19: Set up positive campaign to stimulate development  
SH20: Invest in R&D to study implications for Maasvlakte 2  
H11: Adapt Master Plan, provide additional facilities for inland ships |
| **Non-compliance with standards of security and safety** | SH21: Install monitoring systems  
H12: Impose penalties, fines, internalize external transport costs to discourage transport costs  
H13: Invest in road and underground transport infrastructure, widen waterways |

5.5. Step IV  Contingency planning

Step IV sets up the signpost monitoring system, specifies the triggers, and identifies the actions to be taken when trigger levels of the signposts are reached. Triggers are very often the performance indicators of an organization. No generic performance indicators exist for ports. However, the performance of seaports is traditionally assessed by comparing throughput, e.g. in terms of tonnage or number of containers handled, while port authority performance indicators measure berth or crane utilization, tonnage handling, and queuing. In the case of stevedore, performance indicators include the number of vessels and cargo handled, the cargo handling rate, containers handled per crane, units per man/shift, number of employees, average hours worked per week. Shipping line performance indicators, on the other hand, are concerned with the possible delays: the average delay to vessel awaiting berths, the average delay alongside berths or non-productive time (Notteboom, 2002).

Table 6 shows the signposts to be set up for each of the vulnerabilities and opportunities presented in Tables 4 and 5, and the possible responsive actions in case of trigger events. The numbers used as triggers are illustrative and need to be researched, as do the selected triggers. The table is by no means complete and is intended only to illustrate the adaptive approach for dealing with uncertainty.
# Table 6: Contingency Planning

<table>
<thead>
<tr>
<th>Vulnerabilities and Opportunities</th>
<th>Contingency Planning</th>
<th>Actions (Reassessment (RE), Corrective (CR), Defensive (DA), Capitalizing (CP)) to be taken in implementation phase</th>
</tr>
</thead>
</table>
| **Container demand grows faster than forecast** | **Monitoring and Trigger System** (active from 2013 onwards) | **DA1:** Use strategic land reserves and form strategic alliance with ports of Amsterdam and Antwerp.  
**CP1:** Speed up expansions.  
**CP2:** Invest in common transshipment hub for ports in Hamburg-Le Havre range at a strategic location.  
**RE1:** Reassess next phase of Master Plan. |
| | | **DA2:** Delay investments, and reduce tariffs.  
**DA3:** Diversify into other industries.  
**CR1:** Cancel further expansions.  
**RE2:** Reassess entire Master Plan. |
| **Container demand grows slower than forecast** | **Monitoring and Trigger System** | **DA4:** Define nautical rules with respect to wind, passing ships, turning circles etc.  
**CR2:** Invest in bollards, fenders, bigger tugboats.  
**CP3:** Adapt infrastructure to handle bigger ships.  
**RE1:** Reassess next phase of Master Plan. |
| | | **DA5:** Negotiate with Euromax phase 1 and adapt one berth to receive larger ships.  
**CR3:** Consider dredging of Eurogeul to increase tidal window; widen Yangtzehaven; adapt one berth for bigger ships and define nautical rules with respect to towage, turning, passing ships, etc.  
**CR4:** Consider common transshipment hub for ports in Hamburg-Le Havre range at a strategic location.  
**RE1:** Reassess next phase of Master Plan. |
| **Mega vessels appear (a)** Ships bigger than 12,500 TEU; smaller than 18,000 TEU appear (draught less than 17.4 meter; length more than 450 meter) | **Monitoring and Trigger System** | **DA6:** Discuss terminal concept with operator.  
**DA7:** Offer reduced rates for shorter dwell time.  
**CR4:** Terminal operator must invest in improving hinterland connections, e.g., in a network of inland container depots and container transferia.  
**RE1:** Reassess next phase of Master Plan. |
| **Mega vessels appear (b)** Berthing or access for ships bigger than 18,000 TEU (draught approx. 18 meter; length more than 450 meter) | **Monitoring and Trigger System** | **DA8:** Extra transport to hinterland not by road, only by inland shipping.  
**CR5:** Terminal operator must invest in improving hinterland connections and in network of inland container terminals and container transferia.  
**RE3:** New agreement over profit sharing with terminal operator. |
| **Mega vessels appear (c)** Handling ships bigger than 18,000 TEU | **Monitoring and Trigger System** | **DA6:** Discuss terminal concept with operator.  
**DA7:** Offer reduced rates for shorter dwell time.  
**CR4:** Terminal operator must invest in improving hinterland connections, e.g., in a network of inland container depots and container transferia.  
**RE1:** Reassess next phase of Master Plan. |
| **Increase in quay/ terminal productivity** | **Monitoring and Trigger System** | **DA8:** Extra transport to hinterland not by road, only by inland shipping.  
**CR5:** Terminal operator must invest in improving hinterland connections and in network of inland container terminals and container transferia.  
**RE3:** New agreement over profit sharing with terminal operator. |
Contingency Planning

<table>
<thead>
<tr>
<th>Vulnerabilities and Opportunities</th>
<th>Monitoring and Trigger System (active from 2013 onwards)</th>
<th>Actions (Reassessment (RE), Corrective (CR), Defensive (DA), Capitalizing (CP)) to be taken in implementation phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modal shift in favour of inland shipping</td>
<td>Monitor modal split. If share for inland shipping greater than 45% take CR-action. If share for inland shipping greater than 55% take RE-action.</td>
<td>CR6: Invest in berths for inland shipping. RE1: Reassess next phase of Master Plan.</td>
</tr>
<tr>
<td>Non-compliance with standards of security and safety</td>
<td>Monitor shipping traffic, road and rail movements, emissions, noise, water quality etc.</td>
<td>CR7: Penalties for the users.</td>
</tr>
</tbody>
</table>

5.6. Step IV  Implementation

In the implementation phase, the plan is implemented. The plan consists of the Master Plan as specified in Step I, the actions specified in Tables 3 and 4 under Step III, and the monitoring system specified in Table 5. During implementation, the signposts might indicate for example, that a vulnerability of the plan has appeared in the form of increased or lowered demand, or that the norms established for safety, security, and the quality of the living environment have been violated. The actions specified in Table 6 would then be implemented.

The land reclamation for Maasvlakte 2 was started in September 2008, and in 2013 the first phase will be fully operational. Many of the actions proposed in Tables 4 to 6 are already being taken by the Port Authority and the literature pertaining to them can be found in the MER documents (Projectorganisatie Maasvlakte 2, 2007).

6. The Adaptive Master Plan

6.1. Impact – Probability (Risk) chart

Risk mapping is a tool used by organizations for managing risks, through first prioritizing them, then deciding which of the risks should be addressed, and subsequently, allocating resources for dealing with them. In this section, we rank the vulnerabilities identified in Step II, on a probability – impact (risk) chart (Figure 7).

The X-axis shows the impact and the Y-axis the probability associated with the vulnerability. The product of the impact and probability is the risk. Thus the vulnerabilities with the highest risk are located in the upper right quadrant. A 1 to 10 scale is used for both impact (1 for little and a 10 for significant impact), and for vulnerability (1 for an unlikely, and a

![Figure 7: Probability–Impact (risk) chart](image-url)
10 for a certain development). The direction of the arrow indicates if the probability and/or impact of the vulnerability can be reduced by the proposed actions. The assessment of the impacts is purely qualitative. All the vulnerabilities identified so far, have been critical and have a (medium to) high impact on the plan, (so, medium to high risk). Since the uncertainties we have identified, have no probabilities attached to them, the values assigned to the vulnerabilities in this graph are questionable. Nevertheless, the graph is useful for the subsequent discussion over how the actions proposed in Steps III and IV, for each of the vulnerabilities, can either lower their impact and/or decrease their likelihood.

6.2. (Fairly) Certain developments

The fairly certain developments lie in the top half of the probability–impact chart. The vulnerabilities in this high-impact high-probability zone need to be addressed.

Land side accessibility is a major vulnerability for the port and the situation will worsen with further development of the port. A shaping action for this vulnerability could be to invest in R&D into innovative solutions (SH1), and employ tactics that will make transport by inland ships competitive (SH2). Mitigations could be in form of new logistic concepts, such as a network of inland container depots and container transferia in the hinterland of the port (M1), trucks that can transport more TEUs at one time, night shifts for road transporters, and improvement in cross border rail connections in Europe (M2. Investment in infrastructure for inland ships (M3) and underground infrastructure could also be possible mitigations (M4).

Crude oil and natural gas prices will increase in the long term, due to growing demand and reduced supply, unless there is breakthrough in the area of alternative cost-efficient sources of energy. A shaping action, to invest in research and development of new technologies (SH3), will increase the chance of this happening, but offers no guarantees.

Deterioration of city-port relations can be prevented by improving the living environment in the city (SH4), and stimulating economic and recreational activities in the port and city area (SH5 and SH6).

6.3. Wildcards or trend-break developments

Wildcards belong at the bottom right corner of the impact-probability chart. Sea level rise, global climate change, credit crisis, terrorist attacks, and policy changes, are all examples of wildcards. Wildcards can only be handled through contingency planning; specific strategies and actions to reduce their impact just in case they do occur is the closest we can come to handling these uncertain developments. Sometimes survival of the organization depends on handling these vulnerabilities.

The great Hanshin earthquake that destroyed the Japanese port of Kobe on January 17, 1995 provides an excellent example of dealing effectively with a wildcard. At that time, Kobe was Japan’s biggest international trade hub and a major production and logistics center. The global impact of closure of the port was mitigated by the fact that a large part of Kobe’s business involved the transshipment of containers and that the container-handling infrastructure was relatively standardized in most Japanese ports. The diversion of container ships to the neighbouring ports was accomplished with relative ease and with minimal delays. The worst fears of the closure of Kobe paralyzing global trade did not materialize (Coulter, 2002).

Some wildcards, relevant for our case study, are listed in Table 3, but are not discussed further.

6.4. Uncertain developments

The uncertain vulnerabilities that we have identified are likely to have a medium to high impact on the plan, and the probability or the level of risk also varies between medium to high (Figure 7). In the planning phase, the available options are, to lower their impact through hedging actions (H) or lower their probability through shaping actions (SH). In the implementation phase, defensive, corrective and capitalizing actions will protect the plan.

Container demand grows faster or slower

The realization of Maasvlakte 2 is planned in stages. New port and industrial areas are created only when there are clients. The optimal condition would be if the market demand for each sector materializes exactly as envisaged in the business case and can be coordinated with the realization of new port areas. Any deviations will have an impact on the business case. However the timing (and volumes) of future market demand remain uncertain.

The capacity and design of the port’s major facilities (such as the shipping channels, berths, equipment, storage areas, the internal road and rail connections and the hinterland connections) are dictated by the traffic forecasts. Increased demand (beyond the bandwidth defined to take into account the uncertainties) presents an opportunity and the contract with the terminal operator should allow the port to benefit from this development. However, unless adequate infrastructure and space is available, this development can lead to congestion in the terminal and in the hinterland, and reduced service. A shaping action would be to negotiate a contract that ensures income from this development (SH11).
A hedging action (H1) would be to plan modular terminals that are flexible and can be expanded or downsized. If demand increases, say by 25%, speeding up expansion plans (CP1) and until that time using the strategic reserve space, and creating alliances with the neighboring ports of Antwerp and Amsterdam (DA1), will reduce the adverse impacts of this development. If demand increases, say by 50%, the ports in the Hamburg-Le-Havre range could invest in a common terminal at a strategic location (CP2). If the demand explodes, the plan would need reassessment.

In case of reduced demand, demand guarantee clauses in the contract with the terminal operator will safeguard the interests of the port authority (SH2). Shaping actions to attract cargo, such as lower tariffs or added service, could reduce the probability of this development (SH1). However, investment in modular and flexible infrastructure (also called building in physical options) easily up-scaled or down-sized, will make diversification into other cargo sectors and markets easier (H3). Diversification in port and non-port related activities will make absorption of losses and cross-subsidization within the port easier (H4/DA3). If demand is less than half of forecast, delay investments (DA2). If demand breaks down, reassess the entire Master Plan (RE2).

Mega vessels appear

Once the land has been reclaimed and the fixed infrastructure such as channels and basins created, the port must be able to accommodate future ships. As technology improves, ships size continues to evolve, in order to utilize the economies of scale. Appearance of ships bigger than the ship size assumed in design of the port infrastructure poses a threat to the plan. The PoR is via the Eurogeul and Maasgeul (see Figure 5), accessible for ships with a draught up to 22.50 meter, (though access for ships with a draught greater than 17.40 m is tide-related). The largest ship in design of Maasvlakte 2 is a 12,500 TEU ship with a length of 382 meter and draught of 17.0 meter. On the basis of this design ship, a depth of NAP -20.0 meter will be provided for safe navigation and berthing. Research has established that ships with a length of 450 meter can carry out all maneuvers, though under certain restriction over wind conditions, other shipping traffic, and speed. Thus, if ships in the range of Malacca-max with a length of 450 meter, a draught of up to 18.0 meter, and a capacity of up to approx. 18,000 TEU were to appear, the development would offer an opportunity for Maasvlakte 2. Redefining nautical rules (H5/DA4) and increasing tariffs (SH14), corrective action (CR2) such as investing in larger capacity bollards, fenders and tugboats, and adapting part of the infrastructure (CP3) could be actions of the Port Authority.

If ships with a length greater than 450 meter, or draught more than 18.0 meter were to appear, depending on their call frequency, measures would be necessary (see Table 6). The probability of ships bigger than Malacca-max appearing in the future can be reduced through shaping actions, whereby organizations such as IMO or European Seaport Organization (ESPO) set up a negative campaign against such vessels, which are bound to place additional demands on port infrastructure and in turn cause extra ecological and societal pressure (SH15). A capitalizing action could be to adapt the Master Plan now (H10). In the event that these vessels do appear, but have a call frequency of say 50 ships a year, a hedging action could be for the shipping companies and the ports in de Hamburg-LeHavre range to invest in a common transshipment hub terminal at a suitable location (CP4). Not all ports would be required to invest in dredging and infrastructure to handle these mega vessels. A defensive action, if the ships call only about once a month, could be to adapt one berth at the existing Euromax terminal in order to handle these ships, since the first 600 meter of Yangtzehaven will be widened to create berths for inland ships (DA5). If the ships call, say 3 times a month, an addition corrective action could be increasing the capacity of Maasgeul and Eurogeul (CR3).

Increased in quay/terminal productivity

Increased productivity (handling speed of containers measured in TEU per quay length or TEU per terminal area) will benefit the terminal operator. The Port Authority must invest in R&D to study the implications of this development (SH18). The terminal operator must give adequate warning if the terminal concept is other than in his business case, and arrive at agreement over the profit sharing with the port (RE3). Therefore, he must ensure that the extra transport is by other means than road (DA8), invest in reducing dwell times of containers, improving hinterland connections and create a network of inland container terminals and container transferia (CR5/SH17). These actions will reduce the adverse impact of this development, namely congestion at the terminal and in the hinterland, reduced service and negative environmental impacts.

Modal shift in favour of inland shipping

If there is a modal shift in the favour of inland shipping (environmental friendly mode of transport compared to road and rail), the positive effects of this development should motivate extra investment by the government, since it is responsible for the construction and maintenance of adequate connections to the hinterland. Investment in additional infrastructure for inland ships (H11/CR6) and measures for promoting the transition from road to water transport (SH19, SH20) would help the port, which will experience only a limited impact from this development.
The port development in the Netherlands is guided through national and European policy documents (national seaport policy documents prepared by the Ministry of Transport, Public Works and Water Management and European policy documents prepared by European Seaport Policy Organization), which set down requirements for the environmental quality, maritime safety, security, ecological values, public health, and spatial planning. In order to remain viable, modern ports must be able to accommodate larger vessels and a much greater volume of throughput more cheaply and efficiently than ever before, increasing the potential for environmental damage. This could result in changes in the national legislation or creation of new European Union Directives geared towards stricter regulations in order to maintain standards of sustainability, safety, and security. These would be risks for the existing Master Plan.

One of the principles underpinning the Maasvlakte 2 construction is that even if shipping traffic increases, security levels in and around the port complex must stay the same. This is why there has been extensive research into which measures can be taken to safeguard the current security levels. Norms have been specified as to the emission of fine dust and Co2, noise and inaccessibility of the port for emergency services. If the required standards of sustainability, safety, and security are not met, due to any reason whatsoever, the policy will be threatened. Installing monitoring systems (SH21), and monitoring and imposing penalties in case of more than 10% increase in the levels specified in the norms, would be corrective actions (CR7).

### 7. Conclusions

The shifting function of a port, as well as the many logistical, technological, and economic uncertainties under which a port must operate, make the planning and design of these complex socio-technical infrastructures very challenging. In order to cope with various uncertainties, traditional systems of engineering practices are increasingly trying to incorporate fundamental properties such as flexibility, versatility, and adaptability into their designs. A designer or a planner can endow the system (subsystem or one or more of its internal degrees of freedom) with characteristics of flexibility and adaptivity, but he still needs to scan and monitor the environment for changes. A framework for managing uncertainty is required, which is where Adaptive Planning comes in.

Adaptive Planning is an approach that identifies, in a structured way, the uncertainty in an existing plan, and subsequently improves its robustness through taking actions either in the planning stage, or by preparing actions in advance that can be taken if an uncertain future materializes, thereby making the original plan effective across a variety of futures (i.e., robust). In this paper we have explained the fundamental principles of Assumption-Based Planning and Adaptive Policy Making, combined elements from the two into an integrated approach, and illustrated the approach through the use of a case study in which the existing Master Plan was made adaptive, by incorporating pro-active actions that aim at seizing opportunities and attempt to shape the external forces.

Building a competitive advantage in a volatile environment, in which the markets are uncertain, rate of technological change is rapid, and the competition intense, requires continuous vigilance and monitoring of the internal as well as external environment. It requires the organization to be proactive in developing strategies to hedge against future uncertainties. The proposed adaptive approach can be used effectively to carry out these demanding and manifold tasks, as has been demonstrated through our case study.

Although extreme and ‘black swan’ events cannot be predicted, addressing them during planning is important. In some cases, survival of the organization can depend on doing so, and at other times they can reveal hidden opportunities. Adaptive Planning raises awareness about the notion of surprise, allows for a structured incorporation of radical fluctuations in the future patterns and trends under analysis, and equips the organizations with new mental categories of radical change, as well as a set of new policies to mitigate their extreme effects.

The paper also suggests that in addition to securing public and private investments, and managing the realization of port expansion and subsequently ensuring optimal performance of service providers, the Port Authority or port owner needs to invest in research and development, and initiate and stimulate innovation. Eventually, monitoring (external developments) and innovation are the tools that will shield ports from uncertainty.

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