Responsible innovation in port development: the Rotterdam Maasvlakte 2 and the Dalian Dayao Bay extension projects

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ABSTRACT

The paper outlines and specifies 'responsible port innovation', introducing the development of a methodological and procedural step-by-step plan for the implementation and evaluation of (responsible) innovations. Subsequently, it uses this as a guideline for the analysis and evaluation of two case-studies. The construction of the Rotterdam Maasvlakte 2 Port meets most of the formulated requirements, though making values more explicit and treating it as a process right from the start could have benefited the project. The Dalian Dayao Port could improve its decision-making procedures in several respects, including the introduction of new methods to handle value tensions. Both projects show that public support is crucial in responsible port innovation and that it should be not only a multi-faceted but also a multi-level strategy.

Key words | case-study research, Dayao Bay project, Maasvlakte 2 project, methodological and procedural step-by-step plan, port development, responsible research and innovation, value management

INTRODUCTION

The ‘northern route’ is no dream anymore: on 10 September 2013 a Chinese ship, the Young Sheng, arrived in the Port of Rotterdam, crossing the Bering Strait, the East Siberian Sea, the Laptev Sea and the Barents Sea, the last one named after an older, Dutch attempt to discover this route. The ship brought two new cranes for the new APMT terminals at Maasvlakte 2. It left the Port of Dalian on 8 August and by taking this route (of 4500 km) it saved over 2 weeks, compared to the traditional southern route through the Suez Canal. It was not the first ship to do this and the number of ships to follow is expected to be limited in the coming 10 years because of the ice, but it nevertheless marks a turning point in sailing. This advantageous route is enabled by present climate change, which, however, also increases the challenges ports face.

Besides environmental issues, world ports have to cope with technological, economic and social problems and developments. Global trade increases, especially because of strongly developing new players such as China, Brazil and other emerging economies. Consequently, ports have to handle increasing cargo volumes and expand their capacities. Concurrently, container ships are becoming bigger and bigger, super container ships now requiring depths of 20 m (e.g. Pettit & Beresford 2009; Taneja 2013). In addition, sustainability issues involving climate change, and air and water pollution as well as growing pressure on scarce resources, besides rapid urbanization issues, require more and more attention. These challenges have to be addressed in a situation in which trends in global trade and environmental regulations are highly uncertain (Taneja 2013), while decision- and policy-making arenas involve more and more (critical) stakeholders, particularly citizens.

Consequently, port development projects, however necessary they are, raise public concerns and resistance, for example in the north of Australia close to the Great Barrier Reef (Fight for the Reef 2014) and the confrontation between local fishermen and big companies in relation to the development of Shatian Port, Guangzhou, in China (Ravesteijn et al. 2014).

Contested innovations gave rise to the emergence of a new field of academic activity: responsible innovation (or responsible research and innovation), which aims to deal with diverging, competing and sometimes conflicting
values, such as safety, sustainability, security, transparency, accountability and privacy in innovation and development trajectories, replacing technology and economy as drivers by a more comprehensive propelling force. Responsible innovation has been conceptually and theoretically worked out into an approach and framework for analysing and evaluating new technologies and other innovations (Owen et al. 2013a). It has also been initiated as a strategy for innovation and research (European Commission 2013).

This paper continues and specifies these efforts, following up with the beginnings of a practical methodological and procedural step-by-step plan with appropriate methods at every step, for research-based responsible innovations and, by implication, for evaluating innovations from a responsible innovation viewpoint. Following up on earlier conceptual and theoretical reflections, it presents and discusses case research data from port extension projects in Dalian and Rotterdam.

Both ports, profiting from the new northern route, are taking responsibility for their operations and are involved in sustainability initiatives. The national and regional policy and development context stimulates this, although it is also responsible for differences in pathways and achievements. In addition, both ports undergo the influence of the global network of ports. The Maasvlakte 2 project is explicitly developed as a ‘sustainable port’, accommodating economic, environmental and social values (Port of Rotterdam 2014). Dalian Port also has broad ambitions, which it shows in its Dayao Bay Port project (Green Port Dalian 2013). These efforts, which are relevant and significant to port development in general, can also help us to develop responsible innovation, conceptually and theoretically (characteristics and mechanisms of responsible innovation) as well as methodologically (scientific tools of responsible innovation). Methodologically, the focus here is on managing value tensions, especially between the port, economic, ecological and social values, to be specified in the cases.

Values, representing ‘lasting convictions’ ultimately relating to a good life or a just society (Van de Poel & Royakkers 2011), are relatively stable, though they and certainly their articulation can change over time. Such changes are not considered here, as the emphasis is on comparing orientations and dealings.

Specific questions are: to what extent can these cases be considered as examples of responsible innovation? How were value tensions dealt with? Was responsible innovation a driver? How could responsible innovation support these and similar efforts? What do we learn from these cases? First, we will introduce responsible innovation and formulate a methodological and procedural step-by-step plan. Subsequently, the focus will be on port development and the two cases. The paper concludes with two sections in which these questions will be answered.

RESponsible INNOvation: FROM THEORY TO PRACTICE

Responsible innovation can be described as innovation co-shaped by all actors involved (including social or economic stakeholders) on the basis of data on impacts and options, evaluated and balanced in terms of ethical values (European Commission 2013). It has come up in a situation in which new technologies and innovations provoke serious public concerns. Cases in point are nanotechnology (Simakova & Coenen 2013) and geoengineering (Parkhill et al. 2013). Ultimate causes are value conflicts, e.g. between efficiency and privacy and between environmental and safety concerns. A successful example is the development and adoption of green energy technologies in some European countries (European Commission 2013).

Responsible innovation is a philosophical–ethical approach (Owen et al. 2013a, b), but in its application it includes the mobilization of a social support base (European Commission 2013). It can be understood as a research-based innovation strategy focussed on analysing, assessing and balancing normative judgements in the whole innovation chain on the basis of a combination of the input of experts and other stakeholders.

Responsible innovation raises two questions. (1) Which fundamental values are involved in an innovation – or broader in the analysis and tackling of a socio-technological problem? Making values explicit is its first merit, to avoid implicit and/or unconscious value considerations and choices. (2) How could diverging, competing or even conflicting values be balanced and reconciled?

Various methods have been put forward to cope with the necessary balancing and bridging efforts, including (social) cost-benefit analysis (CBA), multi-criteria analysis (MCA), logic and ethical theories, considering legal or other thresholds or boundary conditions and value-sensitive design (VSD; Van de Poel & Royakkers 2011). The ideal situation would be to accommodate different values simultaneously, which is the goal of VSD (Van den Hoven 2013), as in the Eastern Scheldt Storm Surge Barrier, the sluices of which protect the Netherlands against flooding while keeping the saltwater ecosystem intact (Van de Poel & Royakkers 2011). Other methods such as MCA aim at
creating an acceptable if not desirable value balance, e.g. in economic and environmental performance, exemplified by the quest of new refrigerants replacing chlorofluorocarbons (Van de Poel 2009). However, trade-offs in values are not always desirable or even possible, e.g. when basic principles or rights are at stake; in such cases establishing boundary conditions might be helpful. The least ideal is the method of one or more dominant values, e.g. efficiency or effectiveness; this goes at the expense of other values (Van de Poel 2009).

All these methods are mostly design and expert-oriented, though social embeddedness is considered essential in responsible innovation, which brings in methods such as stakeholder analysis (Enserink et al. 2010) and process management (De Bruijn & Ten Heuvelhof 2008).

Although basically a process-oriented approach, responsible innovation can also be used to determine whether an innovation is responsible or not and how improvements might be possible, as the examples above illustrate. One of its challenges is a detailed methodological and procedural step-by-step plan for implementation, which could guide research on behalf of innovation and evaluation as well. In our view, such a roadmap should contain at least the following questions and methods, loosely grouped by four responsible innovation dimensions (Owen et al. 2013b; Stilgoe et al. 2015; cf. Ravesteijn & Kroesen 2014).

Reflection

1. A problem analysis: what is the problem? For whom?
   Why?
2. A solution analysis: what counts as a good solution?
3. A technology analysis: which technologies are available?
   Which new developments can be expected?

Deliberation

1. A stakeholder analysis: who is the problem owner? Who is taking the initiative or should do so? Who are the external stakeholders? What are their interests and values? What is their influence?

Anticipation

1. An integrated impact assessment including safety and security risks as well as economic, environmental and social consequences.
2. A value analysis of the core values at stake, based on stakeholder analysis and impact assessment.

Responsiveness

1. Dealing with conflicting values through CBA, VSD or other methods.

2. Feeding the outcomes in the design and development process, e.g. through (Constructive) Technology Assessment methods.

3. Introducing the new technology in collaboration with stakeholders, e.g. by applying methods and experiences from impact assessment research.

We will discuss and evaluate the two cases on the basis of this step-by-step plan.

RESPONSIBLE PORT INNOVATION RESEARCH

Responsible innovation is relevant to port development projects (and infrastructural projects in general), not only because they sometimes occasion public debate and protests, but also because they involve a variety of goals or values, including the double entrepreneurial (or micro-economic) aim and social (or macro-economic) goal (Grigalunas et al. 2001). Particularly, sustainable port projects have a broad set of objectives (Koppies & Stevens BV 2008). It is the mission of responsible innovation to deal with such diversity, especially preventing and addressing value conflicts (Van den Hoven et al. 2012).

Consequently, responsible port innovation can be described as a strategy for research and innovation in port development that considers and reconciles a range of (stakeholder) values, varying from employment, safety, economic growth, participation and liveability to natural values (see Figure 1).

To further give form and substance to the concept and strategy of responsible port innovation case-study research into port development is relevant, especially in cases where sustainable port development projects are being carried out. There are many such cases, as ports across the world are reorienting their development trajectories in view of present challenges and values (e.g. Cerceau et al. 2014). Two somewhat different directions are visible in this, which can be characterized in terms of the three key values in sustainable development:

1. Ecologically sustainable port development projects or ‘eco-ports’ (addressing profit and planet), building on the experience with eco-cities and eco-industrial parks (e.g. Joss et al. 2013; Vernay et al. 2010). Such projects are particularly implemented in China (e.g. De Jong et al. 2013; Fifth Session 2005, 2006).

2. Socially and ecologically sustainable port projects, which also consider social aspects such as the integration of
ports in cities and the liveability of port cities (people). Such efforts can especially be found all over Europe (e.g. Koppies & Stevens BV 2008; ESPO 2010, 2012).

The Rotterdam Port Maasvlakte 2 and the Dalian Port Dayao Bay expansion projects exemplify these two directions, respectively (Barker 2010) and Green Port Dalian (2013), respectively). We will describe these projects and analyse them with the above step-by-step plan.

The research data for this paper have been collected in several ways. From 2012, both ports are objects of study in a joint Delft University of Technology and Dalian University of Technology research project on responsible port innovation, and both ports have been visited repeatedly. Information has been directly supplied by port staff members in the form of lectures (e.g. Dalian Port Company 2013a; Vellinga 2013a, b) and documents (e.g. Port of Dalian n.d.; Havenvisie 2030 2011), supplemented by grey literature in the form of reports and data available on the internet (e.g. Dalian Port Company 2013b; Port of Rotterdam 2014). The Rotterdam Port Authority is very open and has of material on its website. We also profited from the long-term cooperation in research and education between the Authority and TU Delft.

Dalian, the work was facilitated by representatives of the University of Technology and the Port Company.

THE MAASVLAKTE 2 PROJECT, ROTTERDAM PORT

Introduction

Rotterdam Port is the largest port in Europe and with a 2012 volume of 11.87 million TEUs (twenty-foot equivalent units), number 11 in the top 50 world container ports (World Shipping Council 2013; Port of Rotterdam 2014; Vellinga 2013b; Pesch & Ravesteijn 2013). As Europe’s logistical nerve centre the port facilitates the needs of a hinterland with 40,000,000 consumers. Between 1962 and 2004 it was the world’s busiest port, but this position has been overtaken by Shanghai and Singapore. In 2006 it was the sixth, in 2008 it was the ninth and in 2009 it was the world’s 10th largest container port. In 2011 Rotterdam Port was the world’s fifth largest port in terms of annual cargo tonnage. The port covers some 105 square kilometres.

The landlord is the Rotterdam Port Authority. Originally, it was a branch of service of the Municipality of Rotterdam, but since 2004 it has been an independent
company with two shareholders: the Rotterdam Municipality and the Dutch State.

Core values or their articulation can change over time, but presently those of the Rotterdam Port Authority are as follows:

- Technical values, especially accessibility, efficiency and safety.
- Business and economic development values, especially profit, entrepreneurial reputation and contribution to the national economy.
- Ecological values, especially a clean port, with low noise and low carbon use and emissions.
- Social values, especially employment, welfare, recreation and democracy (Port of Rotterdam 2014; Van der Lei & Ligtvoet 2012).

Throughout the years, the port authorities have undertaken a series of port extension projects in order to keep up with developments in international trade and shipping technologies, particularly the increasing size of the (container) ships. Last in line is the Maasvlakte 2 project (see Figure 2). The Rotterdam Port Authority embarked on this project in 2008, after a planning trajectory that goes back to the 1990s. It was the biggest engineering project in the Netherlands after the Delta Works. The complete port was expected to be operational in 2013, which actually happened.

**Policy backgrounds**

Basically, the Rotterdam Port aimed to improve or at least consolidate its position as a world port, but in ways fitting in with existing local, provincial, national and European laws and regulation and acceptable to, if not supported by, the citizens of Rotterdam and the general public (Havenvisie 2030 2011, Port of Rotterdam 2014; Vellinga 2013b).

As a city participating in the international Clinton Climate Initiative, founded by the Clinton Foundation in 2006, Rotterdam fights climate change through the Rotterdam Climate Initiative and the Rotterdam Port joins the effort to become ‘carbon neutral’, or at least to reduce CO₂ emissions. It could be considered a case of corporate social responsibility, in which the Port Authority safeguarded the approval, execution and acceptance of the project, while working on its reputation as well, the latter both in business and sustainability.

**Project description**

The Maasvlakte 2 project is part of the bigger Rotterdam Mainport Development project, which embraces two other (sub-)projects, aimed at further developing the Existing Rotterdam Area initiative (a series of projects to make better use of the existing port area and to improve the quality of the living environment), carried out by the Municipality of Rotterdam, and the creation of 750 hectares of nature and recreation area (on Midden-IJsselmonde and to the north of Rotterdam), in which the province of South Holland takes the lead (Vellinga 2013a; Pesch & Ravesteijn 2013).

The port project itself consists of the construction of new port area and the associated environmental compensation for damage to protected nature. One activity is land reclamation (carried out by the involved project organization, a consortium of companies: PUMA), embracing approximately 2,000 hectares, behind a 4 km dike. Approximately 1,000 hectares will be used by port-related industries. The accompanying Compensation of Nature project has two parts, involving the dunes of Delfland and a sea bed protection area, carried out by several ministries.

Container terminal operators APM Terminals and Rotterdam World Gateway (RWG) began construction of
their terminals in 2012. RWG is the main competitor for European Container Terminals, currently the biggest terminal operator in Rotterdam. RWG's terminal will include a 20 m deep dock and its own railroad station, and it will be capable of handling 2.35 million containers annually.

**Project goals**

The goals of the Maasvlakte 2 project were (and are) ambitious: to continue and safeguard the position of Rotterdam as a world port and to improve the liveability of the region, explicitly referred to as the 'double goal' (Port of Rotterdam 2014). To effect this ambition, the Maasvlakte 2 project contained the following (ecological and social) sustainability aspects (Port of Rotterdam 2014; Vellinga 2013a):

- Design: the selected 'cut-through variant' (the new port is connected with the sea through the old port, not directly) is compact, fits into the coastline and is safe.
- Construction: reuse of blocks and quarry stone and smart sand extraction (deep holes, instead of over a broad surface).
- Layout: efficient land use.
- Operation: sustainable industry and distribution, tendering container terminals (tenders were judged on sustainability, counting for 20%).
- Energy and process industry (industrial ecology-like connections).
- Transport: modal shift from road to railway and waterway, especially the latter.
- Dialogue, with non-governmental organizations (NGOs).

In addition, the Rotterdam Port Authority advances flexibility for sustainability reasons through temporal and multifunctional use of provisions (Taneja 2013). With all of this, Maasvlakte 2 should become one of the most sustainable port areas in the world (Port of Rotterdam 2014).

**Management of values**

How did the Rotterdam Port Authority deal with diverging, competing and conflicting values? Of course, they considered thresholds or boundary conditions, to meet all legal demands, not least from a much-requiring Europe. The cut-through variant can be considered a case of VSD, with a choice in favour of the design that was not expected to disturb or deteriorate protected nature values (see Figure 3).

MCA was applied in the case of the tender for terminal companies, where bids were assessed on sustainability for 20% (Hertzberger 2010). To this purpose, APM Terminals plans to use electrically driven lift-automated guided vehicles, which strongly reduce CO2 emissions in comparison with the traditional diesel-fuelled vehicles. In addition, APM performs its own fight to meet and reconcile different values through smart solutions, including extra-large cranes for productivity reasons, zero tolerance for unsafety and a green office building (APM Terminals 2014).

CBA has played a major role in all deliberations about the project proposal, on the basis of a multitude of reports (e.g. CPB et al. 2001; GHR 1998a, b, c; Port of Rotterdam 2014).

Dialogue was clearly used in the contacts with social stakeholders. In 2008, the Quality Control Round Table was founded by 13 parties, based on a covenant (DCMR Milieudienst Rijnmond 2011) providing a framework for the monitoring and evaluation of the agreements about the Project Mainport Rotterdam. Six government bodies, six NGOs and the Rotterdam Port Authority discuss the progress of the complete project (both Maasvlakte 2, the related nature compensation, other new nature and a series of other liveability projects) and the solution of eventual problems during half-yearly meetings, guided by an independent chairperson (presently, the former minister Sybilla Dekker) (see for stakeholder issues and agreements, Vellinga (2013a)).

Not all NGOs were included, however, and some environmental organizations remained concerned about the impact on the environment, particularly the Dutch branch of Friends of the Earth. After years of tensions, the
Rotterdam Port Authority and this NGO made an agreement in 2009, through which the Authority prevented legal proceedings to be instituted against it. The Authority would see to it that harmful submissions would be 10% less than expected in the environmental impact studies, more than legally obliged, and, in exchange, Friends of the Earth would stop its resistance. In 2011, an elaborated version was presented, which contains a whole range of measures proposed, including the promotion of clean shipping and an exploration of the use of onshore electricity (Minder schadelijke stoffen door akkoord Milieudefensie en Havenbedrijf 2013).

THE DAYAO BAY EXTENSION PROJECT, DALIAN PORT

Introduction

The Port of Dalian, lying at the southern tip of Liaodong Peninsula, is the most northern ice-free port in China and number 17 in the top 50 world container ports, in 2012 handling a volume of 8.06 million TEUs (World Shipping Council 2013). As the largest multi-purpose port in Northeast China and the ‘trade gateway’ to the Pacific, it is serving seaports in North Asia, East Asia and the Pacific Rim (Port of Dalian brochure n.d.). It is a port that has experienced a fast growth in the past decades, profiting from the opening-up of China at the end of the 1970s.

The port is owned and managed by the state-owned Dalian Port Company, established in 2005 (Dalian Port Company 2013a). Being a state-owned company, Dalian Port gets supervision as well as financial support from central government branches such as the National Development and Reform Commission, the Assets Supervision and Administration Commission, the Ministry of Transportation (MT) and the Ministry of Environmental Protection, as well as their subordinate bureaus in Liaoning Province and Dalian Municipality. More than just a listed company in Hong Kong and Shanghai, taking annual profit as its main goal, Dalian Port is actually implementing the meta policy for environmental protection (see below), its performance being used as a feedback to local as well as central government. This policy and feedback constitute the initial motive for its eco-port building effort and the driving force in its expansion activities.

The core values of Dalian Port seem to be comparable with those of Rotterdam:

1. Technical values, especially efficiency and safety.
2. Business and economic development values, especially profit and growth of the national income.
3. Ecological values, especially a clean port and low carbon use and emissions.
4. Social values, especially welfare (Green Port Dalian 2013; Chinese Shipping 2013).

In the course of the time, Dalian Port has undertaken a series of extension projects (see Figure 4; Port of Dalian 2012). It has a ‘one core two wings and one island two bays’ policy, with the old port area in the city and the northern Dayao Bay as the core, and the coast zones on both sides and north of the Dalian peninsula as the wings (Dalian Port Company 2013a), including Changxing Island and Taiping Bay.

Policy backgrounds

In 2005, top leaders in the Fifth Session of the Sixteenth Central Committee of the Chinese Communist Party clearly demonstrated their concern about the sustainability of China’s development (Fifth Session 2005a). Turning to an open and competitive economy, it was said that, at the same time, China rapidly consumed its environmental resources. Therefore, for the first time, ‘building a resource-saving and environment-friendly society’, as a meta policy, was written into the 5-year plan (2006–2010), which is the crucial guideline for mapping strategies of economic development, setting growth targets and launching reforms in China.

The plan also put forward 22 quantitative targets. To be noticed most is that, in the time span from 2006 to 2010, the
total discharge of major pollutants of SO2 and CO2 should drop by 10% compared to levels of 2005 (Fifth Session 2006). MT held a national conference to clear out the future policies in implementing the 2005 strategy. In 2007, the minister of MT raised the widely discussed question of how to transform the growth mode in the transportation industry, which started a change in both policy goals and organization performance assessment (Li 2007).

According to another regulation, ‘Opinions of the State Council on Further Implementing the Strategy of Revitalizing the Old Industrial Bases Including Northeast China’, issued in 2009, Dalian Dayao Bay Bonded Zone was acknowledged as the core of the Dalian Northeast Asian international shipping hub, and also the node connecting Suifeng Comprehensive Bonded Zone and Shenyang Bonded Logistics Center, which comprises the premises for bonded logistics and processing industry in the Northeast Region.

Consequently, Dalian Port was offered allegiance for its expansion and its development as an eco-port, guaranteeing its cooperation with the Dalian Municipality as well as financial support from statutory actors and loans from banks. The total investment for port expansion was over 10 billion Yuan. In 2013, the Dalian Port Group announced it was to invest 1.2 billion yuan in ecological port development and operations over the next 5–5 years, to turn the harbour into an advanced, high-tech port with good economic returns, low energy use and little pollution (Chinese Shipping 2013). In its port planning and building, Changxing Island, Taiping Bay and Dayao Bay Ports definitely have priority. The Group optimistically estimated that the port greening will cover 95% of the total area; the rate of water reuse will reach 55%; and public satisfaction with the environment of the port will be more than 80%.

**Project description**

Dayao Bay is one of the eight port zones of Dalian Port and is bordered immediately by the Dalian Economic and Technology Development Zone. The Dayao Port is a new port and it has been under construction in various stages since the 1980s, with the fourth phase of construction to be finished in the near future (Port of Dayao 2013). The project comprises the building of 10 berths in total. The construction of four of them (with a handling capacity of 2.6 million tons per year) started in 1988 and they were operational in 1993. However, in view of realized and expected cargo volumes, there was a pressing need to continue constructing the other six new berths.

**Project goals**

Dalian Port’s development goal is to consolidate and strengthen its position as the main port in Northeast China, to officially become the Northeast Asia Shipping Centre and to play a major role in creating this centre, at the same time stimulating the development of port-related industry and the city of Dalian in general. The Dayao Bay project plays a major role in the regional economic development and has attracted a lot of attention from statutory actors at various levels.

The Port is profiling itself as an innovative and green port, with regard to the latter in its planning focusing on the following:

- **Low-carbon infrastructure construction**, such as ships using onshore electricity and the application of efficient light bulbs.
- **Application of low-carbon transportation equipment**. For example, rubber-tire container gantry cranes using electricity instead of oil as power source.
- **Application of clean energy**. For example, port vehicles and machines using natural gas instead of oil as fuel (Dalian Port Company 2013a).

In 2013, the Dalian Port Group signed an agreement with the Dalian Environmental Protection Bureau, namely ‘A Corporative Frame on Promoting a Green Port in Dalian’, which set a timetable and arranged other practical details for 10 projects (Green Port Dalian 2013). The 10 ‘Eco-green Projects’ are as follows:

- **Building a port–city integration eco-demonstration zone** in Taiping Bay by using a low-carbon environmental rail traffic system.
- **Building a low-carbon logistics port** by relying on new technologies of energy saving, low costs and green materials.
- **Applying technologies of energy substitution** such as substituting oil with gas or with electricity, solar and onshore power supply, accomplishing the substitution of oil by gas for 10,000 container trailers, substituting oil by electricity for loading fields and bridges in the port area in 3 years, and using green energy-saving automatic container-handling bridges in the newly built port area for a clean operation.
- **Adjusting the functional layout and professional running of terminals** in order to improve bulk cargo dust control.
- **Building a green port transportation system** as a way of optimizing port logistics and clean transportation.
• Building professional service terminals targeting circular economic zones.
• Building environmental equipment manufacturing harbour industrial zones to boost the development of the environmental protection industry.
• Optimizing and adjusting liquefied terminal distribution, establishing a spill oil monitoring system and developing an ecological-type chemical port.
• Perfecting the port and terminal environmental risk emergency measures and contingency system.
• Retrofitting the LED (light-emitting diode) road lighting system within the port area, treating small boilers and conducting eco-greening of the port.

As for the Dayao Bay project, the goals were to accommodate rapidly increasing cargo handling demands through the improvement and expansion of Dalian Port Dayao Bay facilities, to thereby contribute to the economic development of the region, while at the same time improving efficiency and safety as well as considering environmental and liveability aspects (Evaluation Dayao Port 2006). The first signals are that targets were achieved (Evaluation Dayao Port 2006).

Management of values

How were different values dealt with in the Dayao Port panning? Unfortunately, conclusive data on the insides of policy-and decision-making as well as the design and development of the project are lacking, but still a few preliminary observations can be made (see e.g. Global Link Management 2005; Dalian Port Company 2003). The environmental goals and efforts as outlined above are impressive and could give rise to de facto VSD of port facilities, which, for example, are both efficient and clean. However, it seems also obvious that the project has been mainly embarked on in relation to increasing trade volumes and economic development in general. A second top priority has been safety of operations. Although social and environmental goals and values were clearly included, it looks as though this happened to the extent that the primary values of efficiency and safety were not endangered, although some choices, e.g. transitioning from oil to gas and other energy sources, suggest trading off economic and social-environmental issues through MCA. As elsewhere in China, CBA was probably a main method (Chen 2004, 2005; Coto-Millan et al. 2010), though things are changing, in general and in Dalian Port. The public was not involved, though public resistance could make a difference, as appeared from the fact that a chemical industry project (with regard to p-xylene) was cancelled under pressure of the public opinion, although this was especially a conflict between the people and the political authorities (Port of Dalian 2012).

ANALYSIS AND DISCUSSION

To what extent can both cases be considered as examples of responsible port innovation? The port expansion projects of Maasvlakte 2 and Dayao Bay were set up from a clear double-target perspective, serving both business and social–environmental values. Business and ecological soundness were both addressed in building Maasvlakte 2. A good example is APM Terminals, operating and innovating within the frame of their contract with the Rotterdam Port Authority, which aims to realize both economic and social benefits through electrifying its operation. Dalian Port aspires to revolutionizing its energy system, in which electricity plays a major part. However, these and other ecological sustainability plans are still largely on the drawing board and thus a promise for the future.

Consequently, the Maasvlakte 2 project also scores more convincingly on our responsible innovation step-by-step plan, as appears from the overview indicating which points and questions were more or less consciously addressed in the decision-making on both projects (Table 1).

Main value tensions exist between business in combination with other economic values (especially profit and economic development respectively) and, on the one hand, ecological values (like a clean port) and, on the other hand, social values (like welfare). Table 2 shows which methods were more or less explicitly used to overcome these tensions.

Rotterdam Port seems to have used a host of available methods, design and expert-oriented methods as well as process and stakeholder engagement methods. Dalian Port seems to have used the proven methods, though transitioning to newer ones.

Although the combination of technology development and business and development economics constitutes today’s dominant driver behind port development, in the case of the Maasvlakte 2 project there was a more comprehensive driving force, in which other factors also played a main part. Technologically (e.g. cut-through variant), institutionally (Quality Control Round Table) and socially (the dialogue with Friends of the Earth), the approach was very much what responsible innovation stands for. However, were technology and economics still not the major force...
behind the project, with all sustainability and responsibility efforts part of an elaborate and sophisticated corporate social responsibility and reputation management strategy (cf. Van de Poel & Royakkers 2014)? There is no conclusive evidence here, but one thing is sure: if, ultimately, the project would only have been possible using this ‘impression management’ strategy, then the business case and the responsible innovation case would have coalesced!

The Dayao Bay extension project also served multiple targets, though the driver is rather government policies than responsible innovation in itself. Also, although the data collected are far from sufficient, business and development values seemed to be decisive. Nevertheless, the environmental initiatives have been impressive and improvement is in the air, in which the increasingly concerned and involved public may play a major part (Alagappa 2004).

From the perspective of responsible innovation, both cases also elicit suggestions for improvement as to their continued development and future port development in general. Responsible innovation focusses on values and value differences, which results in the need for a value analysis of projects and stakeholder positions (like Van der Lei & Ligtvoet (2015) did) as well as a search for and reflection on possibilities to resolve oppositions. Not all methods for dealing with diverging values have indeed been used in both projects. Data showing that reasoning on the basis of logic and ethical theories has consciously and systematically played a role in the decision-making are lacking for both projects. In the Maasvlakte 2 case, it looks as though – in the final analysis – utilitarian considerations (CBA) went together with other ethical considerations, e.g. pertaining to procedural justice (dialogue) and sustainability ethics (intergenerational solidarity). In both cases, decision-making might have gained from making value positions and considerations much more explicit.

### Table 1 | Responsible Innovation in the Maasvlakte 2 and Dayao Bay extension projects

<table>
<thead>
<tr>
<th>Steps</th>
<th>Addressed in Rotterdam?</th>
<th>Explanation/source</th>
<th>Addressed in Dalian?</th>
<th>Explanation/source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Problem analysis</td>
<td>Yes</td>
<td>Project documents, Port of Rotterdam (2014)</td>
<td>Yes, though at national level</td>
<td>Five-year plan 2006–2010</td>
</tr>
<tr>
<td>2 Solution analysis</td>
<td>Yes</td>
<td>Long-term vision based on technology forecasting and back-casting; strategic reports, Havenvisie 2030 (2011), Port of Rotterdam (2014)</td>
<td>Yes</td>
<td>Dalian Port Company (2013a)</td>
</tr>
<tr>
<td>3 Technology analysis</td>
<td>Yes</td>
<td>Strategic reports, Havenvisie 2030 (2011), Port of Rotterdam (2014)</td>
<td>Yes</td>
<td>Dalian Port Company (2013a)</td>
</tr>
<tr>
<td>4 Stakeholder analysis</td>
<td>Yes</td>
<td>Project documents, Port of Rotterdam (2014)</td>
<td>No data, probably only internal stakeholders</td>
<td></td>
</tr>
<tr>
<td>5 Integrated impact assessment</td>
<td>Only separate assessment studies</td>
<td>CBA, environmental and other impact study reports, GHR (1998a, b, c), Port of Rotterdam (2014)</td>
<td>Only environmental impact study</td>
<td>Dalian Port Company (2013a)</td>
</tr>
<tr>
<td>6 Value analysis</td>
<td>Limited</td>
<td>Van der Lei &amp; Ligtvoet (2012)</td>
<td>No data</td>
<td></td>
</tr>
<tr>
<td>7 Handling conflicting values</td>
<td>Intuitively, not systematically</td>
<td>Van der Lei &amp; Ligtvoet (2012)</td>
<td>Intuitively, not systematically</td>
<td>Changxing Island project’s ocean EIA report (2013)</td>
</tr>
<tr>
<td>8 Feeding outcomes in design and development</td>
<td>Yes, in as far as outcomes were present</td>
<td>Cut-through variant and other sustainability aspects, Port of Rotterdam (2014)</td>
<td>No data</td>
<td></td>
</tr>
<tr>
<td>9 Introduction with stakeholders</td>
<td>Limited in (re)design and development, full in monitoring</td>
<td>Agreement with Friends of the Earth, Port of Rotterdam (2014), DCMR (2011)</td>
<td>Adaptations on the basis of public pressure</td>
<td>Vellinga (2013b)</td>
</tr>
</tbody>
</table>

### Table 2 | Value management in the Maasvlakte 2 and Dayao Bay extension projects

<table>
<thead>
<tr>
<th>Value tensions/ports</th>
<th>Port of Rotterdam</th>
<th>Port of Dalian</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit &amp; economic development vs clean port</td>
<td>CBA, VSD, legal boundaries, MCA, dialogue</td>
<td>Dominant values, CBA, MCA, VSD-in-development</td>
</tr>
<tr>
<td>Profit and economic development vs welfare</td>
<td>CBA, MCA, dialogue</td>
<td>Dominant values, CBA, MCA</td>
</tr>
</tbody>
</table>
In the Maasvlakte 2 project, stakeholders manifested themselves – solicited and unsolicited – in several stages (planning stage, monitoring, innovation) and at different levels (port management, social environment). Stakeholders were in a position to co-manage in the Quality Control Round Table, while they also directly negotiated with the Rotterdam Port Authority and not without success. Consequently, it might be concluded that the Maasvlakte 2 project de facto has been run as a process, though a conscious and systematic use of process management right from the start could have avoided events like the clash with Friends of the Earth. Involvement of stakeholders was less clear in the Dayao Bay case, though even here a project was cancelled following public action. It goes without saying that also here process management could have made – and can still make – a difference.

In addition, the Maasvlakte 2 project has some other open ends where responsible innovation could be helpful. A systematic approach in addressing specific sustainability issues has been lacking. In the tender for terminal companies, (ecological) sustainability counted for 20% in the evaluation of the bids. Why 20%? How has this criterion been used precisely? With regard to CBA: what was precisely the business case of Maasvlakte 2? As regards the dialogue with the environmental NGOs the question is how this will result in clean port operations and shipping. The general research question here might be: how to make a decision model to cope with diverging values in design and development?

**CONCLUSION AND FURTHER RESEARCH**

Responsible innovation is a new and promising approach in addressing social problems through new technology and in dealing with diverging values in particular, thus addressing the dilemmas of sustainable development. Following earlier conceptual and theoretical contributions, this paper has formulated a first methodological and procedural step-by-step plan, which is essential for the successful application of responsible innovation. In this paper, it is used as a guideline for the analysis and evaluation of two cases: the Rotterdam Port Maasvlakte 2 and the Dalian Port Dayao Bay extension projects. So, what can we learn from these cases?

Both clearly show the interaction of the technical, institutional and social facets of port development, as well as the broader significance of port innovation for the development of city, region and ultimately the whole country, China or the Netherlands. Responsible innovation is thus not only a multi-faceted approach, but a multi-level approach as well! This introduces coordination problems of value considerations at different levels, including the problem that actors at lower levels ignore higher level decisions.

Both projects also show the crucial part of the public. Port development and other large technological projects involve a great many businesses and social stakeholders. Also, these actors might change their opinion – and their values in general – on the basis of new information and insight, while new stakeholders might arise or other relevant developments might take place during the long duration of such a project. Consequently, involving and managing stakeholders deserves special interest in responsible innovation, during the execution of a project and the innovation trajectory as a whole. A range of stakeholder methods could be employed in supporting and shaping socio-technological development innovation and development processes, including process management. These methods are a valuable contribution to the responsible innovation toolkit, enabling a broad set of stakeholders and their values to be explicitly and systematically addressed.

The Rotterdam Port Authority wishes to transfer its approach of sustainable port building to other locations in the world, preferably with some participation (Port of Rotterdam 2014). Is that possible? Could responsible port innovation be an internationally attractive approach and business case? Could it replace economy and technology as the main propelling force? And if Dalian Port realizes its ambitious environmental goals and will involve stakeholders as well, would that be transferable in China? And elsewhere? Further port research might give answers. As appears from the two cases, ports are not only spearheads in globalization, they are also laboratories and hot spots of sustainability and responsibility, from which academics can learn a lot.

**ACKNOWLEDGEMENTS**

The research for this paper was partly supported by the National Natural Science Foundation of China (no. 71203017) and the Key Project of the National Social Science Foundation of China (no. 12AGL010).

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First received 11 February 2015; accepted in revised form 13 May 2015. Available online 2 June 2015.