SUSTAINABLE PORT DEVELOPMENT IN THE NETHERLANDS – FRAMEWORK FOR A COMPREHENSIVE APPROACH APPLIED TO AMSTERDAM PORT

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ABSTRACT

Sustainable development is presently a major critical issue, also for the maritime sector. Seaports require sustainable solutions for the challenges they are facing: increasing demand for space, expanding energy needs, growing mobility (trade and traffic) and the effects of climate change. The ultimate goal from a sustainability point of view is to address these challenges in such a way that a balance is found between social, ecological and economic interests. A comprehensive approach taking into account smart (here: integrated and cost-effective) solutions is called for. In the present paper, we introduce a framework for such an approach. With this framework, port management can be supported in realizing its ambitions regarding the three tracks ‘use of space’, ‘energy needs’ and ‘mobility’, and in anticipating changing circumstances with smart solutions. The framework is demonstrated with an application to Amsterdam port. The results of this application are used to situate the proposed framework and to recommend issues for port management and further development of the framework.

Keywords: port development, sustainability, comprehensive planning

1. INTRODUCTION

Sustainable development is presently a major critical issue, also for the maritime sector. Seaports frequently require sustainable solutions for the challenges they are facing such as increasing demand for space, expanding energy needs, growing mobility (trade and traffic) and the effects of climate change, in particular sea level rise. The ultimate goal from a sustainability point of view is to address these challenges in such a way that a balance is

found between social ('people'), ecological ('planet') and economic ('profit' and 'prosperity') interests.

In EU port policy, sustainability has been a major issue since the 1990's. Chlomoudis and Pallis [1], for instance, point out "the implications of a wide range of EU policy developments aiming to promote the competitiveness of the European port industry within the context of a long-term sustainable mobility strategy" (p. xii). Also sector-driven initiatives should be noted such as EcoPorts. This initiative, started in 1999 by a group of European ports, aims at creating a level playing field in Europe in port-related sustainability issues, and stimulates pro-active behaviour of ports regarding sustainable management of ports and the logistic chains of which they are part of [2].

Initiatives taken by the Dutch port sector are illustrative for the European strive for a more sustainable sector. For instance, the port of Amsterdam – after Rotterdam the largest seaports in the Netherlands and one of the leading ports in EcoPorts – is addressing the issue of obtaining more efficiency in the use of space, energy and mobility in its latest policy outlook [3]. At the same time, relevant lines of thought can be found at Dutch national policy level that may contribute to an integrated approach for sustainable port development.

Using the lines of thought identified by reviewing relevant initiatives of the Dutch port sector, we propose a framework for a comprehensive approach for sustainable port development that takes into account smart (here: integrated and cost-effective) solutions [4]. With this framework, port management can be supported in deciding upon challenges regarding use of space, energy needs and mobility, and adapting for changing circumstances such as sea level rise. The ultimate goal is to support port management in its search for an optimal balance between social, ecological and economic interests and in maintaining this balance with smart solutions.

The remainder of this paper is divided into four sections. Section 2, Background, starts with addressing the question 'What is sustainable port development?'. Then, recent initiatives of the Dutch port sector regarding sustainable development are reviewed and the impetus to an integrated approach is given. Section 3, Framework for sustainable port development, presents our framework for a comprehensive approach sustainable development of ports that takes smart solutions into account. To illustrate the use of our framework, Section 4, Application of the framework to Amsterdam port, applies it to the Amsterdam port area. For each of the above-described challenges regarding space, energy and mobility, we indicate to what extent the port of Amsterdam already is state-of-the-practice in terms of smart solutions that contribute to sustainable development. Next steps towards a more sustainable development will also be indicated. Section 5 discusses the results of the application and Section 6 concludes.

2. BACKGROUND

2.1 What is sustainable port development?

Since we are fully aware of the impact of our economic activities on ecology and climate, sustainable development is strongly promoted. The concept of sustainable development has become increasingly associated with the integration of social ('people'), ecological ('planet')

and economic ('profit' and 'prosperity') aspects. In 1989, the World Commission on Environment and Development (Brundtland Commission) gave the following definition of sustainable development: development that meets the needs of the present without compromising the ability of future generations to meet their own needs [5].

A major challenge is to apply this definition to sustainable port development. Traditionally, port development aims at more efficient cargo-handling processes. This leads first of all to transport-efficiency gains – lower service times and costs – for port users (freight carriers) and commercial benefits for terminal operators and other port players such as port management. When transport-efficiency gains are passed on to society, it leads to the ultimate (public) goal of port development, namely, "to increase producers' surplus of those who originate the exports passing through it, and to increase the consumers' surplus of those who ultimately consume the imports passing through it" ([6], p. 211).

Dekker [7] defined a sustainable port as a port that focuses on the following five issues:

- Sound (commercial) economic performance in terms of turnover, added value and employment;
- Optimal utilization of cargo-handling capacity;
- Efficient use of space;
- A strong economic relationship between the port and its hinterland; and
- Minimized negative impact on the environment.

The optimal balance between these five issues differs per port since each port differs in terms of function, size and composition of cargo flows, economic importance, hinterland and hinterland connections. The complexity of this balance due to the diversity of aspects involved (economy, space, energy, mobility, etc.) requires a tailor-made approach to deal with it (see further).

So, what we call here the 'conventional' ultimate (public) goal of port development as formulated by Goss [6] offers a sound basis for defining the concept of sustainable port development. However, the term 'benefits' (and the terms 'producers' surplus' and 'consumers' surplus' in the definition of Goss) need here to be interpreted broadly by taking into account social and environmental aspects as well. This refers to the broad or social welfare concept.

2.2 How the Dutch port sector deals with sustainability

The question is how the port sector already brings the concept of sustainability into practice. In answering this question, we limit ourselves here to the Dutch port sector and provide only a rough sketch of the main lines of thought by briefly describing some interesting public and private initiatives.

In November 2008, the Dutch Ministry of Transport, Public Works and Water Management published the report "Seaports as hubs towards sustainability" [8]. In this policy

document, it is observed that the Dutch seaports have already initiated various 'sustainable' initiatives. For instance, they accommodate a substantial amount of wind energy turbines - producing 754 megawatt - and Rotterdam port acts globally as puller of initiatives in the field of CO2-reduction and storage. Further steps are however necessary. The report proposes a focus on the following themes:

- Air quality.
- Energy, CO2 and residual flows.
- Use of space.
- Preservation and development of nature.
- Water quality and management.

Several actions are proposed including subsidies for innovation and sustainability in ports and shipping, a more intensive cooperation between seaports and improvement of inland ports to promote inland shipping. Port management is considered to play a crucial role in stimulating and coordinating sustainable initiatives in its port area. Recent guidelines of the national government for 'sustainable procurement' (of various kinds of products and services) are a stimulus for further realisation.

An interesting example of the role of port management can be found in Rotterdam. Due to the size of this port (in terms of surface area as well as throughput volumes) and its contribution to the Dutch economy, Port of Rotterdam plays a major role in several initiatives (see [9]), including:

- Rotterdam Climate Initiative: a program in which four parties including Port of Rotterdam, the municipality of Rotterdam and industries cooperate to reach the following targets: in 2025 50% CO2-reduction compared to 1990, preparing for the effects of climate change and strengthening the economy of the region [10];
- The Traffic Company: an initiative of several parties including Port of Rotterdam, focussed on traffic management (optimal use of road capacity) and mobility management (reduction of car traffic, particularly during rush hours) [11]; and
- Maasvlakte 2 – sustainable port: with this initiative, Port of Rotterdam establishes a sustainable second seawards expansion of the port (Maasvlakte 2) by seeking for sustainable solutions for the whole lifecycle of the project. An interesting example concerns a required modal shift (for container terminal operators) from truck to train/inland vessel: from 47% road transport in 2005 tot 35% in 2033 [12].

A major issue for many port authorities is the introduction of shore-side electrical power to ships at berth (cold ironing). The (main and auxiliary) engines of the ships can then be turned off, which limits emissions of contaminants such as NOx and PM10, and noise production. A major critical success factor in widely applying cold ironing is the development and introduction of international standards for plugs and frequencies (e.g., [13]). Sufficient

and 'clean' production of electrical power for cold ironing is another issue that has to be resolved.

Regarding private initiatives, interesting examples can be found in all Dutch ports. In the Amsterdam port area, Greenmills, a major producer of biodiesel and biogas, has plans for setting up a new plant. The plant is planned to be able to meet the annual energy needs of about 35,000 households (electricity) and 150,000 cars (biodiesel, bio-ethanol and biogas). Dutch companies are also involved in further development of cold ironing.

2.3 Towards an integrated approach

The above-described lines of thought and initiatives of the Dutch port sector reflect also the challenges the port sector is facing internationally. These challenges include:

- Clever use of space: limitation of the use of space by applying smart solutions.
- Energy efficiency: reduction of carbon dioxide emissions by 1) energy saving, 2) use of sustainable energy sources, en 3) clean use of conventional energy sources (oil, coal, etc.).
- Transport efficiency: reduction of transport movements and using sustainable energy sources.

To maximize the result of investment in sustainable port development (long term: climate neutrality) and to reduce the cost of it an integrated approach is required. The ultimate goal is then to find the optimal strategy to meet the above-mentioned challenges for sustainable port development. The next section proposes a framework for sustainable development of ports that takes into account smart solutions in order to be able to integrate the challenges regarding use of space, energy needs and mobility, and adapting for changing circumstances in a strategy for sustainable port development.

3. FRAMEWORK FOR SUSTAINABLE PORT DEVELOPMENT

Ports constitute a particular challenge for sustainable development due to convergence of different functions (node in transport-logistic networks, location for industries and often also drain off point for rivers) and, as a consequence, tasks (in particular regarding space, energy and mobility). Being aware of this challenge, we propose a framework for sustainable port development that focuses on making step-by-step progress towards the long-term goal: a zero overall effect of the port on the climate. The flow diagram below presents this framework.

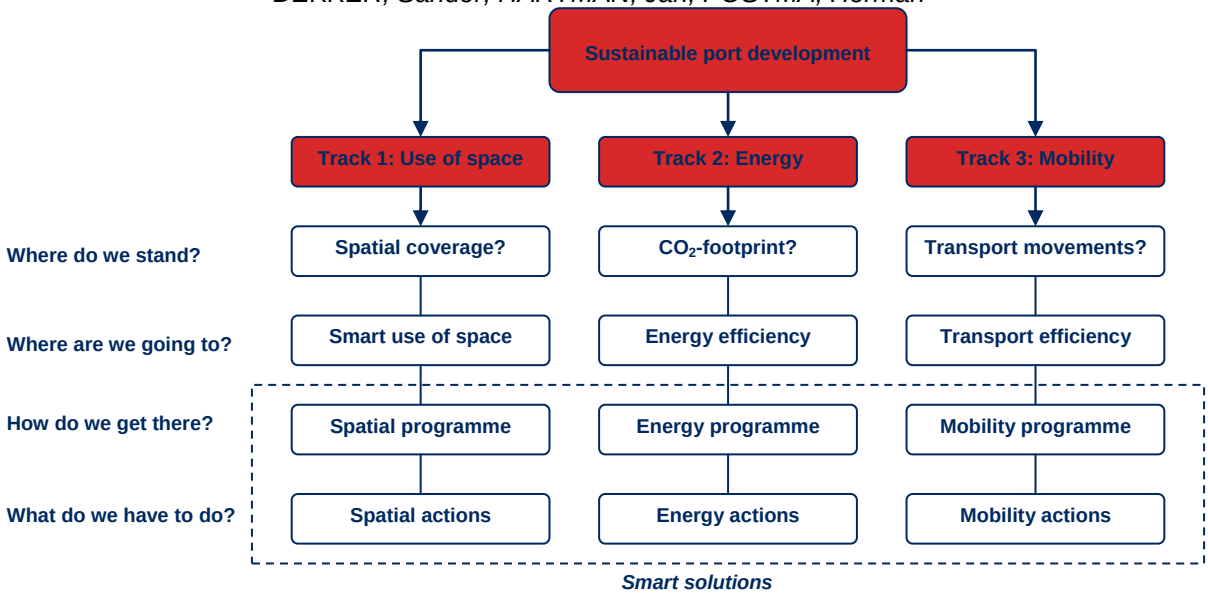

Figure 1 - Framework for sustainable port development.

We distinguish three tracks in our framework: space, energy and mobility. In order to be able the take the next step, four questions are essential for each of these steps:

- Where do we stand?
- Where are we going to?
- How do we get there?
- What do we have to do?

Answering the first question requires describing the present situation. The second question refers to goals and ambitions of the port, which should be determined by the specific market and institutional setting in which the port operates. The third question is answered in terms of long-term port strategies and programs which are strongly affected by the specific markets in which a port operates. The fourth question addresses the translation of strategies and programs into actions and measures.

The above-described framework comprising three tracks and four questions is universally applicable. However, the answers on the questions for each of the tracks are determined by the specific situation in which a port operates. For example, the challenges of a major hub such as Rotterdam and Antwerp differ from those of a relatively small port that operates in a niche market. And a fully privatized port sets different goals than a publicly owned port that sets also social goals such as preserving employment. This requires tailor-made solutions as will be illustrated in the next section in which the framework is applied to the port of Amsterdam.

4. APPLICATION OF THE FRAMEWORK TO AMSTERDAM PORT

To demonstrate our framework for sustainable port development, it has been applied to the port of Amsterdam. The focus of this application is mainly on the environmental ('planet') component. The data for this application has come from the latest (April 2008) concept of the policy view (outlook) for the period up to 2020 [3]. This outlook addresses spatial issues as well as energy and mobility issues. We have paid particular attention to the newest basin in Amsterdam port: the Afrikahaven (see the map below).

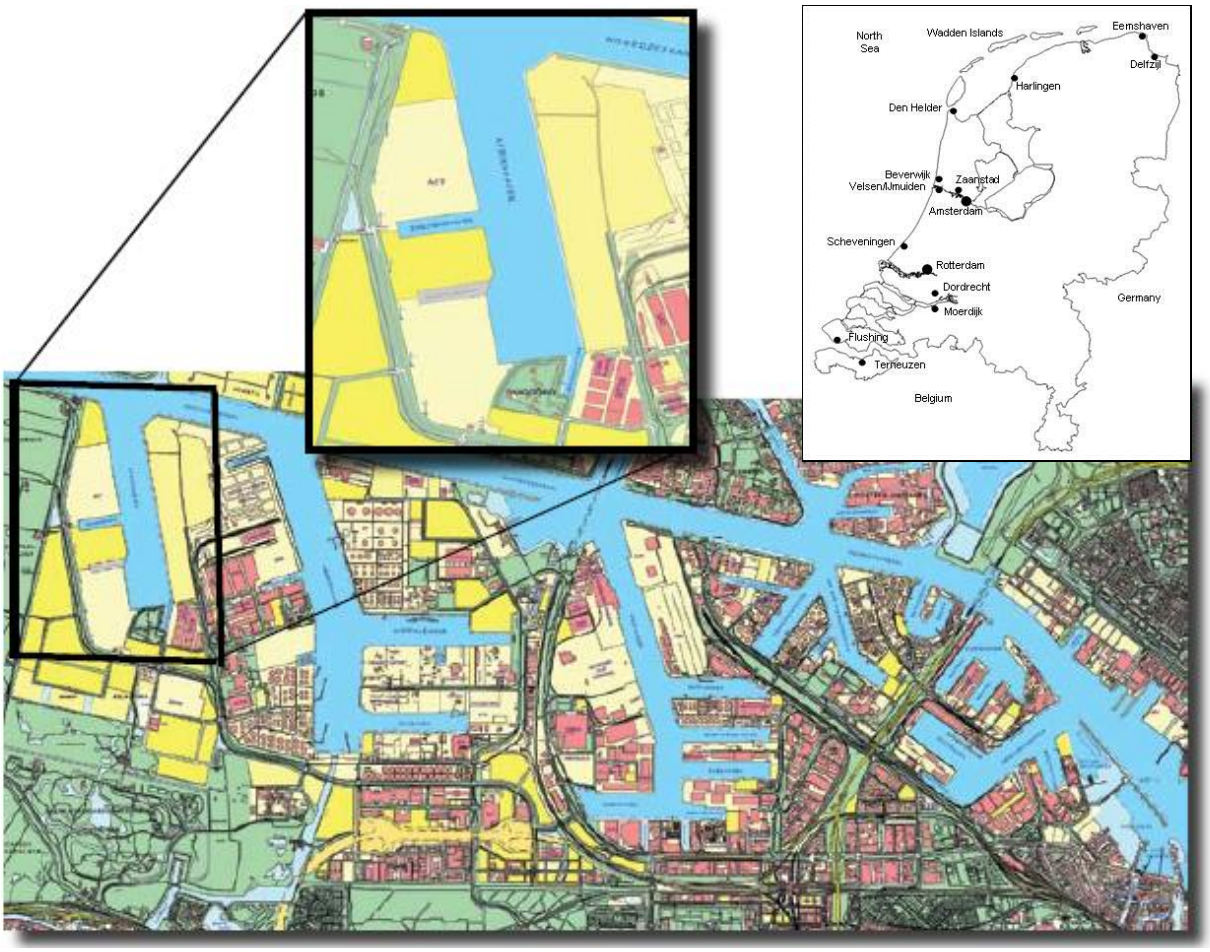

Figure 2 - Maps of Amsterdam port and the Afrikahaven, and an overview of seaports in the Netherlands.

4.1 Track 1: Use of space

Regarding the space track, the outlook of Amsterdam Port argues that after years of sufficient space the port is reaching it limits. Attention is given to the following spatial targets:

- The desired and realisable growth in the port of Amsterdam until 2020 (shipping of in excess of 125 million tons of goods) should be accommodated within the existing port area.

- Retaining the system of lease hold.

- After 2020 only expanding into the nearby region if this is socially broadly acceptable and if advantages outweigh the disadvantages.

- Retaining the strategic reserve space.

- Retaining the total reserve terrains of the port for port activities.

The outlook further shows that Amsterdam port management has taken the initiative. On the grounds of our pursuit 'smart use of space' marginal comments can be placed about the spatial targets: keeping a strategic reserve and keeping it for sole use of port activities might be an obstacle for a cleverer (here: mixed) use.

As answer to the question 'where are we going to?' we propose three solution directions for where the port of Amsterdam and especially the Afrikahaven can make smart use of the available space:

1. Combining and intensifying functions so that with less space the same - of maybe even more - profit can be gained.

2. Location policy so that the port (in fact the municipality of Amsterdam, which is the owner of Amsterdam Port) has a guidance instrument in order to allow development in accordance with the spatial targets (see above).

3. Adaptable solutions allowing the port to adapt to changing circumstances.

We answer the question 'how do we get there?' as follows:

Ad 1 Combining and intensifying functions. Find out which claims of space consecutively can be combined with other claims because some functions only make a temporary claim on the space. Also integration of functions gives possibilities. Look if it is possible to combine port activities with urban ones such as recreation. In the port of Amsterdam, the so-called Minervahaven area has already been restructured and prepared for renewed use of space that is more in line with present port users' demands. Also, on a smaller scale, provisions have been made such as cycle tracks though the port area. This complies with the following citation out of the policy outlook that is concerned with revitalisation of the relationship between port and city: "The port will be made more attractive for recreationists and tourists. Inhabitants of Amsterdam will take the port to their hearts because – long time remaining invisible – it will belong more to the city".

Ad 2 Location policy. Location policy is an important instrument to direct the development in line with the spatial targets. Location policy makes also in less economic times sure that no businesses are allowed on a place which they should not be located. With companies who want to expand or establish in the port area agreements are being made for better use of the land and quays. We propose to combine this with other space-saving possibilities such as co-siting, the concept where various different businesses use the same facilities.

Ad 3 Adaptable solutions. Ports are then able to respond adequately to the dynamics of the market and of the environment as well. For example, ports can adapt then to changing demands and sea level rise.

As answer to the question 'what do we have to do?' the following actions can be mentioned:

Clever combining of functions. The port authorities could in the environmental planning of the Afrikahaven combine in a clever way various functions. Examples of this are night versus day activities en winter versus summer activities.

Active acquisition policy combined with clustering, environmental permits and leasing. Examples of actions within the framework for the Afrikahaven are an active acquisition policy where the port authorities can attract businesses who comply with criteria of sustainability, or reserving space for the generation of clean energy. Also in the outlook of Amsterdam Port reference is made to such actions and investing on the level is being realised in the short tem (see also the next section).

Lease rates in ports are always differentiated on the basis of a number of different aspects such as length of the agreement, extra provisions and competition position inside and outside the port. Generally, we propose lease charges to be coupled to on the actual use of space: businesses that store more efficient pay less lease.

We propose for the cargo-handling facilities (cranes and quays) to be completely based on adaptable solutions. An example is the use of floating cranes that can be modularly adapted to meet any changing demands within the port area and the expected sea level rise. It should be noted that Amsterdam does presently not suffer from rise in sea level as it lies downstream from the locks at IJmuiden. Another example is the use of hollow quays on the basis of a caisson construction which can simply be moved (floating) and filled with dredgers' sludge (the port of Amsterdam itself has already been cleaned). Shippers can be stimulated to use 'foldable containers' which take up less space when empty.

4.2 Track 2: Energy

It appears from the outlook of Amsterdam Port that Amsterdam is conscious of the importance of sustainable development of the port. Not only do they mention sustainability as a precondition for development, but they have the ambition to make the port of Amsterdam in 2020 the most sustainable port in Europe. That they are consciously going further than just acknowledging sustainability and climate change appears out the fact that in the outlook also an inventory is made regarding energy. So, it appears out of the outlook that Greenmills is going to produce biodiesel out of waste (see also Section 2.2), there are different locations where wind turbines have been placed and the lighting of the entrance channel (between Amsterdam and the North Sea) works off solar energy.

In her outlook for energy, Amsterdam Port has formulated the following targets as answer to the question 'where are we going to?':

- Calculating the port's CO2-footprint and monitoring the annual CO2 emissions.

- Delivering a suitable contribution to the reduction of the CO2 emission in appliance with the climate ambitions of the City Council of Amsterdam (40% reduction by 2025).

- Setting up one regional environmental organisation allowing efficient and transparent communications with businesses.

- Stimulating and/or forcing of measures in the area of energy saving and sustainable energy. This must lead to a reduction in noise pollution and the emission of dangerous particles.

- Simplifying criteria of how sustainability is measured by contributing to setting up a (inter)national benchmark system.

For the question 'how do we get there?' we propose for the energy track the use of the following instruments:

1. Legal regulation.

2. Offering energy infrastructure as a way of regulation.

3. Social regulation.

Ad 1 Legal regulation. With a use zone plan and permits, Amsterdam Port can stimulate saving and sustaining energy. The use zone plan gives the opportunity in an early stadium to stipulate requirements for sustainability. So can an environment zone be put in place or space can be reserved for the application of sustainable energy generation. An additional refinement can be achieved by the permit granting route. This instrument can only be used when comparing different businesses; it can also be used as location instrument and stimulating clustering of businesses. For example, optimal use of residual warmth is stimulated by placing businesses which have a similar thermal profile next to each other. Also requirements can be made pertaining to the use of sustainable energy or its application in parking management.

Ad 2 Offering energy infrastructure as a way of regulation. The instrument fits closely with legal regulation. If the port management decides to lay a thermal network instead of a gas network then businesses are compelled to use the thermal network for space heating and hot tap water. Particularly the neighbouring office location of the Afrikahaven would offer a possibility of using, via the thermal network, the residual warmth for heating the office buildings.

Ad 3 Social regulation. In addition to the 'hard' regulation possibilities, port management can use the 'soft' or social regulation. Here would be looked for cooperation between businesses and instances or use would be made of the existing or future desired image of the port as guide for sustainable development. The port of Amsterdam has a very strong position in the energy sector, particularly in the area of fuel, and can use this to attract companies in the bio-fuel sector. For this, space has to be made in use zone plan and permit granting. Considering the fact that in the Afrikahaven there is an established fuel storage company (Vopak) and taking into account the Greenmills-initiative (see Section 2.2), there are already starting points for second generation bio-fuel activities in the port. Another way of

stimulating the energy track is by inspiring businesses to take on other activities. The port of Amsterdam will start a sustainable fund to which businesses can apply to. Also Port of Amsterdam tries to support companies with knowledge and the availability of networking. Also within this instrument fall the closures of energy covenants with existing and new companies in which agreements are made over saving and sustaining of energy.

In answering the question 'what do we have to do?' we propose the following actions:

Establish a thermal network. Take the Afrikahaven up in a large-scale thermal network. Similar to what is already established on a smaller scale, the region in which the port is located, could take the initiative to assess the feasibility of a much larger thermal network. This could be a ring line for delivering warm water in the whole area around Amsterdam port. In this way, residual warmth could be more efficiently distributed saving a large amount of natural gas. The question is of course who is going to pay the infrastructure.

Furthermore, the port management can expand its cold ironing facilities for inland shipping and assess feasibility of offering cold ironing feasibilities for sea-going vessels. This is in accordance with present plans of Amsterdam Port.

Amsterdam Port can - with help of legal and social instruments - entice or compel businesses in Afrikahaven to use sustainable energy. Here is thought of buying in sustainable electricity generated by wind turbines – around Afrikahaven there are enough wind turbines that together can generate electricity for 40,000 households – or sun panels on warehouses and office buildings.

4.3 Track 3: Mobility

As target stands centrally the term 'transport efficiency'. One of the aspects of transport efficiency is the use of sustainable energy sources such as bio-fuel. The aim is the no-effect level, where there are no negative impacts on health and nature resulting from emissions and noise. In addition to the use of sustainable energy sources, play other aspects a role in obtaining transport efficiency such as the optimisation of passenger and freight transport. Here, the aim is preventing stagnation, wasting and overloading the network where negative effects of mobility (such as congestion, air and noise pollution, the degradation of living conditions) can be prevented.

The question is where the port of Amsterdam presently stands in relation to her aims on transport efficiency.

Concerning passenger transport:

- For transporting employees in the port area, since 2003 there has been a bus service from the nearby rail station ('Amsterdam Sloterdijk') to the port area of Amsterdam.
- The accessibility per public transport (bus) is reasonable. There is a bus four times per hour from Amsterdam Sloterdijk to the port area of Amsterdam.

- The public transport company in the Amsterdam area sails with a boat four times per hour during the rush hour between Amsterdam and IJmuiden. The boat as yet does not make a stop at the port area of Amsterdam.

- The accessibility of the Afrikahaven by road can be better. The regional road network around Amsterdam is very full; nearby highways are at the rush hour times very congested.

Concerning freight transport:

- The modal split in the Amsterdam port area is:

  - Inland navigation: 43%
  - Road: 53%
  - Rail: 4%

- Capacity of inland waterways is large enough to absorb the growth in inland navigation. For example, the Amsterdam–Rijnkanaal – the channel that connects Amsterdam with the river Rhine – has at present utilisation rate of only 50%.

- Clean vessels (ships with 'Green Award certificate' or a 'Segregated ballast tank') receive a discount in the port area of between 7 to 17%.

- Daily sails an innovative inland water vessel along industrial areas picking up containers and transports them to/from storage areas. By this, containers are taken of the road reducing overloading the transport network in and around the port area.

Concerning sustainable energy sources applicable to transport:

- Concession holder of the public transport in the port area of Amsterdam uses the most modern diesel engines.

- As far as it is known along side the use of fossil fuels, no use is made (as yet) of sustainable fuels such as bio-fuel and hydrogen.

As answer to the question 'where are we going to?' the outlook gives the following targets:

- More transport by rail and ship and less by truck, less pollution per ship, reduced use of fuel and introduction of the second generation bio-fuels.

- At the latest in 2016, there has to be in operation a new sea lock at IJmuiden.

- For all modalities (transport by road, over water and by rail) the accessibility of the port should so good that the steam of goods can be safely, sustainable and competitively handled.

Taking into account the concreteness of the targets, the question 'how do we get there?' is also answered.

In answering the question 'what do we have to do?' we propose for the port area the following three measures:

Facilitate waterborne freight transport. Develop at the east side of Amsterdam an extra hub for freight transport over water. In this way, a reduction can be made of freight transport movements over the road. For the Amsterdam road network this would be a relief since Amsterdam is located between the proposed location and the port area.

Cleaner public transport. In the present situation, the concession holder uses diesel engines. Fitting within the targets of the CO2 emissions should reduced by 2020, in the following tendering procedure for the public transport in the region requirements should be included that the public transport companies must increase the use of sustainable fuels such as hydrogen.

Environmental zoning of the port area. One of the possibilities to reduce polluting particles in and around the Afrikahaven is to create an environmental zone where there are entrance restrictions for polluting vehicles. Presently, only environmental zones are in place to improve the air quality in urban areas. A zone could be created to improve the air quality in and around the Afrikahaven. So can the Afrikahaven play also a part in relation to freight transport on the road in improving air quality. Furthermore, the coal terminal in the Afrikahaven has created an innovative air quality monitoring system which can give sufficient time anticipation to any possible breaking of the limit.

5. RESULTS AND DISCUSSION

From the application of our framework to Amsterdam port it appears that the port is already taking several initiatives to become a more sustainable port. However, the three tracks 'use of space', 'energy' and 'mobility' find themselves in different stadia of development. In the space track, the port finds itself in the stadium of wakening up and the next step is answering the question 'where are we going to?'. In the energy track, the next question to answer is 'how do we get there?'. In the mobility track, Amsterdam port is in a stadium further and already up to answering the questions 'what do we have to do?'.

Regarding the measures it is possible to make use of cross relationships between the tracks. The measure 'Environmental zoning in the port area' in the mobility track clearly has an overlap with the space track. Combined with the measure 'Completing a thermal network' in the energy track, an integrated approach can be established. Such an approach is cost effective and can count on sufficient (public and commercial) support.

Examples of smart solutions are floating cranes and hollow quays which can easily be moved to other locations and are multifunctional in use. Also the thermal network is an interesting example of a smart solution; it contributes to an efficient match of supply of and demand for energy in the port area. Linking the thermal network with cold ironing facilities would be interesting in view of the potentially large energy needs of such facilities. In the mobility track, waterborne transport (freight and passengers) is an interesting solution; it contributes to relieving the roads and a better utilization of inland waterways, which is a cost effective type of transport infrastructure due to its long life span.

The application case has been analysed in a qualitative way by indicating sustainable strategies and solutions based on best practices in the (Dutch) port sector for the tracks of space, energy and mobility (see Section 2.2). The number of tracks could be expanded, for instance, with the tracks 'water quality' and 'waste'. Further development of our framework requires a clear division of roles and responsibilities. It is therefore recommended to expand the framework with a module that takes care of the question 'which party is responsible for which action?'. The proposed strategies and measures can then be coupled to responsible parties (public and private) after which the funding can be arranged.

The focus of our application was mainly on the environmental ('planet') component. But what would be the results of the application when also the social ('people') component is explicitly taken into account? The different tracks may lead then to opposing and conflicting choices; less CO2-producing activities in a port area does not necessarily lead to, for instance, enhanced employment. This issue should be dealt with in further development of the proposed framework; striving for an optimal balance between 'people', 'planet' and 'profit'/'prosperity' should then be kept in mind.

6. CONCLUSIONS AND RECOMMENDATIONS

In the present paper, we have introduced a comprehensive framework for sustainable port development. With this framework, port management can be supported in realizing its ambitions regarding the three tracks 'use of space', 'energy needs' and 'mobility', and in anticipating changing circumstances such as market dynamics.

Application of the framework to Amsterdam port pointed out that a port can be in different stadia of development for each of the tracks. This requires accurate identification of the next steps towards more sustainability; for each of the tracks these steps may differ in terms of concreteness and level of detail. Port management should be aware of this when remarks are made on the degree of overall sustainability of the port, and when a strategy is formulated for becoming more sustainable.

It appeared further that it is possible to make use of cross relationships between the different tracks. An integrated approach can then be implemented that may be cost effective for port management as well as for the industries in the port. It can count then on sufficient public and commercial support. This is particularly required when less conventional solutions will be applied; such solutions have a potentially large contribution to 'people' and 'planet' but their net contribution to 'profit' may still be uncertain.

Further development of our framework will be more interesting for port management when the number of tracks is expanded (e.g., with the tracks 'water quality' and 'waste') and an extra module is added that takes care of the question 'which party is responsible for which action?'. Also the issue of potential opposing and conflicting choices regarding 'people', 'planet' and 'profit'/'prosperity' should be accounted for in further development of our framework.

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