Capacity with a pOsitive enviRonmEntal and societAL footprInt: portS in the future era

COREALIS
THE PORT OF THE FUTURE

D4.1 Green Port Policy functionalities in the Port of the Future Serious Game

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Table of Contents

List of Tables

List of Figures

List of Acronyms

Abbreviation / acronym	Description
ESI	Environment Ship Index
GHG	GreenHouse Gas
ISO	International Organization for Standardization
KPI	Key Performance Indicator
LL	Living Lab
NGO	Non-Governmental Organization
PoFSG	Port of the Future Serious Game
PPP	People, Planet and Prosperity (or Profit)
RTM	Requirement Traceability Matrix
RVO	The Netherlands Enterprise Agency

Executive Summary

The Port of the Future Serious Game (PoFSG, ©Deltares) is an innovative and interactive training and simulation game that is used to explore the feasibility and sustainability of port-city developments. The game aims to raise awareness on present and future port-city challenges. It can be used for stimulating discussions/debate amongst stakeholders and/or for educational purposes. The game provides a fictional but realistic port environment in which different scenarios aimed at specific port-city challenges can be explored. The game contains a set of measures (game cards), and qualitative indicators describing the effects of these scenarios and measures on society (people), the natural environment (planet), and the economy (prosperity). The players need to account for the different stakeholder perspectives and balance the effects for people, planet and prosperity (PPP) in their decisions. The target audience for the PoFSG are port planners and stakeholders that want to explore present and future port-city development strategies.

The PoFSG is a multi-stakeholder game where players are subdivided into different stakeholder groups. The game contains stakeholder roles (cards), measures (cards), scenarios (in digital simulation environment), events (cards), cheat sheets (cards) and a digital simulation environment (software). In the game, players need to define a strategy from their stakeholder perspective to design their "Port of the Future" in several game rounds. The different stakeholder groups have to debate and convince each other to select the final 2 measures to be implemented in each single round. During the game, the facilitator has a crucial role in setting the scene for the gameplay, stimulating debate between the stakeholders and reflecting on the choices being made and their effects. Each session ends with a reflection on the gameplay and evaluation of the lessons learnt.

A first edition of the PoFSG was developed in 2015 [1]. This manual is part of the 2nd game edition. The development of this 2nd edition was funded by the EU-H2020 COREALIS project as well as the Deltares strategic research programme 'Infrastructure for Waterborne Transport'. The development started with a scoping phase in which we collected requirements from the COREALIS partners as well as existing and potential future users. The implementation of these requirements took place in development sprints. In each sprint, the requirements were revised and ranked in order of priority for implementation. The new features with the highest priority were implemented in the PoFSG. Benchmarking tests were conducted within Deltares and, after final optimisations, externally during plenary meetings with the COREALIS consortium. Based on the results of these tests, we refined and prioritized the requirements with the users for the next development sprint.

This document describes the concept, elements, development process, playing rules and background information for the final delivery of the PoFSG 2nd edition.

1. Introduction

1.1 Port of the future

Seaports are important transport hubs located in complex environments with interactions between physical networks (e.g., infrastructure, transport networks), socio-economic aspects (e.g., employment opportunities, port-city relations), and ecological system processes (e.g., sediment transport, fish migration and habitat dynamics [2]). Besides their generally positive impacts on trade, economic growth and employment, port developments can also have negative environmental (e.g., water/air pollution, loss of habitats) and social impacts (e.g., loss of livelihoods, relocation of communities). These effects could also have negative consequences for the port itself in terms of costs and delays due to fines, lawsuits or clean-up costs. Therefore, there is increasing pressure from shareholders, customers and society to make ports more sustainable and to better harmonize them with the natural and socio-economic environment in which they are located [2] [3]. At the same time, the "port of the future" has to respond to global trends such as digitalization, the energy transition, and climate change. To assist port stakeholders to explore alternative futures, understand different stakeholder perspectives, and facilitate strategic decision-making, the Port of the Future Serious Game (PoFSG) was developed.

1.2 The three pillars of sustainability: People, Planet and Prosperity

Port developments support the increasing trend of trade through shipping. The future development models of ports should account for both growth and sustainability, also referred to as "green growth" [3]. The concept of green growth enables policymakers and companies to identify successful strategies they can adopt and pitfalls they need to avoid in implementing sustainable policies. The term "sustainable" is inclusive and can refer to many interdisciplinary fields. For this reason, sustainability usually focuses on three fundamental aspects. These aspects are the society, the environment and the economy, or "People, Planet and Prosperity" (PPP, see Figure 1). This concept forms the basis of the Port of the Future Serious Game (PoFSG).

Looking at each indicator, "people" corresponds to fair and beneficial business practices towards labour and the community of the port region. The category 'people' is comprehensive and can include different groups, such as the people who live directly within the port area, the residents of the greater port area, the passengers of the ships and NGOs (Non-Governmental Organizations). A port authority dedicated to the PPP principles seeks to provide benefit as many stakeholder groups as possible and not to exploit or endanger any of them.

Secondly, "planet" refers to environmental practices. Responsible stakeholders aim to minimise environmental impacts. The development or expansion of a port should strive to avoid the disturbance of natural processes (such as water and sediment flows) and the destruction of natural ecosystems (especially those that are fragile, scarce or contain high biodiversity). Furthermore, "planet" refers to reducing the ecological footprint of ports by, for example, reducing CO_2 emissions, optimizing energy consumption and reducing waste and pollution.

Finally, "prosperity" refers to the direct financial income of port, indirect profits by improving operational efficiency as well as benefits to the port-city. Therefore, it is a measure of the actual economic impact of the port on the port-city environment [4].

Figure 1 Visualization of the People, Planet and Prosperity (PPP) concept, which aims for sustainable development through harmonizing social, environmental and economic aspects.

1.3 The Port of the Future Serious Game (PoFSG)

To address the challenges of port-cities and facilitate port stakeholders in the transition to the port of the future, the Port of the Future Serious Game (PoFSG, ©Deltares) was developed [1]. Serious games simulate real-world events and processes to help players gaining insights into the potential consequences of their choices a playful manner. The PoFSG aims at raising awareness on present and future port-city challenges, so as to support the port stakeholders in achieving sustainable development. The game applies a fictional but realistic environment, different scenarios aimed at specific port-city challenges, a set of measures, and a qualitative collection of indicators that provide information on the effects of these scenarios and measures on society (people), the natural environment (planet) and the economy (prosperity). By introducing real-world challenges associated with port development and going through a decision-making process for selecting sustainable measures, the stakeholders can experience aspects of sustainable port development first hand through the serious game. The game consists of multiple rounds in which the stakeholders can select several measures fitting their strategy. The game is supported by a desktop application which visualises the measures and their scores on People, Planet and Prosperity (PPP).

The 1st edition of the PoFSG was developed in 2015 by a consortium of the Netherlands Enterprise Agency (RVO), Delft University of Technology, Wageningen Marine Research, World Wildlife Fund for Nature, Boskalis, Royal Haskoning DHV and Deltares. This document provides the user manual and technical background of the 2nd edition of the PoFSG that was developed as part of the EU-H2020 COREALIS (Capacity with a pOsitive enviRovnmEntal and societAL footprInt: portS in the future era) project (Grant Agreement No. 768994) running from 2018 to 2020.

1.4 Aims of the game

The PoFSG can be used to achieve several goals. First, the game can help city-port stakeholders to explore, better understand and discuss different port aspects based on the three pillars: People (society), Planet (environment) and Prosperity (economy). Second, the PoFSG can assist in educating players on integral or multidisciplinary thinking by combining requirements for port

infrastructure and operations with those of ecosystems and society. The game makes trade-offs between these requirements and the allocation of financial resources explicit. Third, the PoFSG facilitates debate and negotiation between stakeholders and stimulates players to account for different stakeholder perspectives in their decisions.

1.5 Target audience

The target audience of the PoFSG are port planners and stakeholders that want to explore future port-city management strategies. The game shows that many different aspects of the port and the port-city are interlinked. If considered together, as is done in the game, they create the potential to develop a sustainable port. The game can also be an aggregation platform for general education, aiming to identify knowledge gaps in sustainable port development. For these reasons, the game can be played by a wide range of players including port authorities, planners, terminal operators, policymakers, private companies, NGOs, environmental organizations, scientists, students and citizens.

1.6 What is new in the 2nd edition

The 1st edition of the game [1] was based on a fictional but realistic port environment with simple game rules, which made it possible to play the game at a wide range of locations worldwide. The game was supported by a set of game cards and a digital simulation environment. These crucial elements made the 1st edition successful and have been maintained in this 2nd edition.

Based on the feedback from existing users and facilitators of the game as well as the COREALIS Living Labs (LLs), the following elements have been changed and/or extended in the 2nd edition:

1) The range of measures is more balanced over the various aspects of port-city development, rather than the focus on 'green' measures in the 1st edition. With this new set of measures, we aim to make the interventions better recognizable and more appealing to a wider range of stakeholders. Furthermore, the wider range of measures puts more emphasis on the interdisciplinary aspects of sustainable port development and the possible trade-offs that need to be made.
2) The key performance indicators (KPIs) and scores of the measures have been re-evaluated. Together with the existing users and the COREALIS LLs, a new set of KPIs was defined, which better connects to the indicators that port-cities use to rate their performance. Based on these new KPIs, the scores of the (existing and new) measures were re-evaluated based on expert judgment.
3) Scenarios and events have been added to trigger debate and conflicts between the stakeholders. The scenarios and events connect to the current trends being relevant for port development (e.g., the energy transition, climate change adaptation) and allow players to focus on specific port development aspects in the gameplay as well as the associated uncertainties.
4) The game cards have been re-designed to be self-explanatory and better fit for stakeholder discussions.
5) The digital simulation environment has been redesigned and it is now more interactive in visualizing the effects of decisions being made by the stakeholders. The new

simulation is more realistic and provides interactive feedback to the players, which facilitates the learning.

6) Supporting materials for the gameplay (e.g., a cheat sheet and stakeholder role cards) have been added. Such materials help players to better understand the rules and procedures of the game.

The structure of this report is as follows. First, Chapter 2 introduces the game concept and elements. Then, Chapter 3 describes the development process from the 1st edition to the 2nd edition. Subsequently, Chapter 4 describes the game rules and procedure. Finally, Chapter 5 provides hints and guidelines for facilitating workshops with the PoFSG.

2. Elements of the game

2.1 Game concept

The PoFSG is a multi-stakeholder game that raises awareness among the players on the interdisciplinary aspects of sustainability and different stakeholder perspectives on port development. Therefore, players are subdivided into different stakeholder groups. Players need to define a strategy from their stakeholder perspective to design their port of the future in several game rounds. Each round represents approximately 10 years. After the teams are formed, the facilitator applies a scenario which affects the initial scores for People, Planet and Profit (PPP scores) and budget. Each scenario can be used to address a particular challenge such as the energy transition, technological innovation or climate change adaptation. In each round, each stakeholder group can select 2 measures to implement its strategy. These measures cost money but can also gain money in time (i.e., through rounds). Furthermore, each measure affects PPP scores. After each stakeholder group has selected 2 measures, the different stakeholder groups have to debate and convince each other to select the final 2 measures to be implemented in that round. By the end of each round, the selected measures and their associated effects on the PPP scores and budget will be visualized in the digital simulation environment.

At the beginning of the following round, the facilitator can run an (unexpected) event which also affects the PPP scores. Events are associated with scenarios and can be used to trigger additional conflict, debate and/or a different way of thinking. Then the procedure of the first-round repeats. A game session usually consists of 3 to 4 playing rounds with a total duration of approximately 2.5 to 3 hours, including discussion and feedback. For optimal discussion between players, the game is usually played with 15 to 30 players distributed over 4 to 6 stakeholder groups. If there are more players, an additional facilitator may be required for an effective game session.

The game consists of the following elements, which are described in more detail in the subsequent sections:

- The facilitator
- Stakeholder roles (cards)
- Measures (cards)
- Scenarios (in simulation environment)
- Events (cards)
- Cheat sheet (cards)
- Digital simulation environment (software)

2.2 The facilitator

The facilitator plays a crucial role in the success of a PoFSG session. The facilitator has a role in setting the scene for the gameplay, introducing the game concept and rules, keeping the time and guiding the players through the gameplay. However, the role of the facilitator entails much more than only making sure that the rules are followed, and that the players stick to the time plan. As the PoFSG is a multi-disciplinary and multi-stakeholder game, the facilitator also has a key role in connecting the different disciplines and stakeholder views. He or she needs to have a thorough understanding of the underlying principles and mechanisms of the game in order to

be able to guide the players through the gameplay, reflect on the choices they make as well as the consequences of these choices for People, Planet, Prosperity and budget. In this way the facilitator plays a crucial role in obtaining (one or more of) the intended objectives of the game (i.e., (1) to raise awareness on the different aspects of port development, (2) to educate the players on integral or multidisciplinary thinking, and (3) to facilitate debate and negotiation between the stakeholders). Chapter 5 discusses the role of the facilitator in more detail and provides guidance and hints for effective game facilitation.

2.3 Stakeholder roles

The success of port management relies on the ability to integrate port developments in the social, economic and environmental system. This requires that port planning must account for demands and objectives of a wide range of stakeholders. Based on the suggestion of experts, the 2nd edition of the game includes eight stakeholder roles that can be selected for the gameplay. Players are divided over different groups, which are each assigned a specific stakeholder role. It is not necessary to use all the roles in one playing session. The facilitator is free to select which roles are fit-for-purpose for the gameplay based on the number of players and the specific game setting (i.e., the relevant stakeholders for the specific port development context under which the game is played at that time). The stakeholder roles available in the game and their descriptions are listed below:

1) Port authority
   Land owner of the port responsible for the planning, maintenance and replacement of the port's basic infrastructure (e.g., quays, basins, channels).
2) Terminal operator
   Owning/leasing space in the port for terminal operations (e.g., handling, storing and transporting of goods and materials).
3) Environmental NGO
   Non-governmental organization aiming to protect and/or restore the environment.
4) Government
   Responsible for policies, legislation and decision making with respect to (amongst others) employment, safety, environment, transportation infrastructure and spatial planning.
5) Local business owner
   Facilitating the industries in the port with supporting services (e.g., accountants, consultants, hotel owners).
6) Investor
   Financing port developments by providing loans; steering by means of loan conditions.
7) Contractor
   Responsible for construction and maintenance works for the port's infrastructure (e.g., dredging and construction).
8) Shipping company
   Providing shipping services (i.e., transporting of goods/materials by ship).

The role cards have a trigonal pyramidal shape with the title on one side and the stakeholder description and corresponding main interests on the other side. An example of a stakeholder role card is presented in Figure 2.

Figure 2 Example of stakeholder role card

2.4 Measures

The measure cards give the players the opportunity to take interventions in the port-city environment and to improve its PPP performance. The measures are grouped in nine overarching categories, namely 1) port development/expansion, 2) hinterland connection, 3) energy, 4) port infrastructure, 5) strategic planning, 6) regulation, 7) technology, 8) public services and 9) environment. The measures in each category are listed in Table 4. The effects of measures on the PPP indicator were scored based on expert judgement. Each PPP indicator is scored on a scale ranging from -5 to 5 (i.e., from very negative to very positive). To avoid players focusing on bookkeeping the PPP values, the measure cards show only whether the effect is positive (+), negative (-) or no-impact (0). The actual scores will be shown when the measures are implemented in the digital simulation environment (not implemented yet). The detailed information on the definition of each measure, PPP scores, costs and benefits are described in Appendix 2.

Figure 3 Example of a measure card with the description and PPP scores on the front-side (left) and QR code on the back-side (right). The icons on the left picture indicate, from top to bottom, construction costs, maintenance costs, and scores for People, Planet and Prosperity, respectively.

Each measure has implementation costs (i.e., initial investment, similar to CAPEX), maintenance/operation costs (i.e., returning costs during the operational lifetime, similar to OPEX) and income (i.e., earnings that fluctuate in time). To optimize the discussion between stakeholders, only costs of construction and maintenance are shown on the card. The calculation of costs and benefits is incorporated in the digital simulation environment.

Each measure card is printed on both sides: the front-side displays the information of a measure; the back-side shows a QR code which can be scanned via the camera of the computer. An example of a measure card is presented in Figure 3.

Table 1 List of measure categories and associated measures.

Measure category	Measures
Port development	• Brownfield port development • Greenfield port development • Island port development • Reclaimed peninsula port development • Offshore floating port development
Hinterland connection	• Increase hinterland transport by road • Increase hinterland transport by railway • Increase hinterland transport by waterway • Increase hinterland transport by air • Increase hinterland transport by pipelines
Energy	• Increase renewable energy production • Provide on-shore power to ships • Optimize power grid for renewables • Electrify port equipment
Port infrastructure	• Create extra shelter for ships (by adjusting the layout) • Deepen channels and basins (bigger ships) • Limit dredging activities (focus on smaller ships) • Upgrade handling equipment • Expand storage infrastructure
Strategic planning	• Develop new port business opportunities • Improve coordination with other ports • Improve employees' expertise • Attract investors
Regulation	• Implement environmental management standard (ISO) • Apply lifecycle asset management • Incentivize green port concessions • Implement Environment Ship Index (ESI) discounts • Implement stricter safety rules • Improve customs procedures
Technology	• Improve IT technology • Install innovative mooring techniques • Implement weather & pollution monitoring system
Public services	• Increase public green space for leisure & recreation • Contribute to public education • Invest in port-related research & innovation • Invest in real estate waterfront development
Environment	• Implement carbon capture storage • Improve waste recycling • Integrate sanitation & wastewater treatment • Natural habitat restoration & rehabilitation • Coastal protection by revetments • Coastal protection through Building with Nature

2.5 Scenarios

Scenarios are alternative projections of how the future might unfold and an appropriate tool to analyse how driving forces may influence future port development. In the game a scenario is a somewhat enhanced or 'amplified' trend to allow players to focus on specific port development aspects in the gameplay and the associated uncertainties, which are presented as unexpected events in the game. The game includes scenarios on climate change adaptation, energy transition, economic stagnation, innovation and sustainable port-city development. For flexibility in the gameplay, a neutral scenario was added, which can be shaped by the facilitator to make the game session fit-for-purpose. Each scenario is equipped with a storyline, learning goals, initial PPP value, budget, and events, which can be flexibly selected by the facilitator. The initial budgets of all scenarios are set to 100.

The implemented scenarios are listed below:

1. Climate change adaptation
2. Energy transition
3. Economic stagnation
4. Innovation
5. Sustainable port-city development
6. Neutral

Annex 3 discusses the scenarios, storylines and effects on PPP scores in more detail.

2.6 Events

Events can be randomly implemented by the facilitator to steer the gameplay. An event can serve two goals. First, it is intended to make the players aware of unexpected disruptions to the port development that may also occur in practice. The event is then used by the game facilitator to introduce an element of uncertainty in policy-making. Second, an event gives the possibility to the game facilitator to respond to developments within the gameplay, organize interaction between players, and steer the discussion to topics not sufficiently considered by the group yet.

In the gameplay, events are presented via a fictional newspaper. Similar to the measure cards, each news card is printed double sided. One side displays the news; the other side shows a QR code which can be scanned via the camera of the computer. An example of a news card is presented in Figure 4.

Figure 4 Example of an event card in the form of "Special news" with the description of the event on the front-side (left) and QR code on the back-side (right).

Since an event is meant to be unexpected, it should be introduced during the later rounds rather than at the beginning of the game. At the point where the event is introduced, PPP values get

new values reflecting the impact of the event. The effects of events on the PPP indicators as applied during the gameplay have been scored based on expert judgement (see Appendix 4). The event will require players to change their strategy and to focus more on other types of measures. Whenever the event is introduced, the facilitator will explain the relevance of the event within the scenario. Events, special news and PPP scores are described in Appendix 4. How events are collocated with each scenario is described below.

1) Climate change adaptation

The 'Climate change adaptation' scenario is supported with one economic event (Companies not satisfied by the port policy) or unemployment event (Big strike: workers fear to lose their jobs) as an alternate and one climate-related event. The climate-related event can be an extreme weather or sea level rise, depending on the PPP values that resulted from previous rounds.

2) Energy transition

This scenario is completed with a port infrastructure related event (Port infrastructure not ready), which reflects the possibility that the port is not ready for the transition. The second event is either unemployment of traditional jobs event or air pollution. The facilitator can make the selection.

3) Economic stagnation

What is unexpected in the economic stagnation scenario can be a climate change event or an unemployment event (Big strike: workers fear to lose their jobs). The purpose of these two events is reminding players not solely to focus on the improvement of profit.

4) Innovation

Similar to the "energy transition" scenario, this scenario is associated with an infrastructure related event (Chaos due to IT network breakdown). Another event can either be unemployment of traditional job event or air pollution event, in reminding the players concerning of People or Planet.

5) Sustainable port-city development

The first event played in this scenario can be either an unemployment event (Big strike: workers fear to lose their jobs) or an economic event (Recession!). Then a climate change event is displayed to emphases the cooperation of city and port fighting with climate change. Which climate change event is used depends on the PPP scores resulted from the previous round.

2.7 Cheat Sheet

The cheat sheet provides a brief introduction of the game, an overview of each round, description of measure card, and the list of measures on the other side. The summary of each round helps players to understand the game rules. The card schematic leads the card reading. The list of measures facilitates the players to target the relevant measures. The cheat sheet is presented in Figure 5.

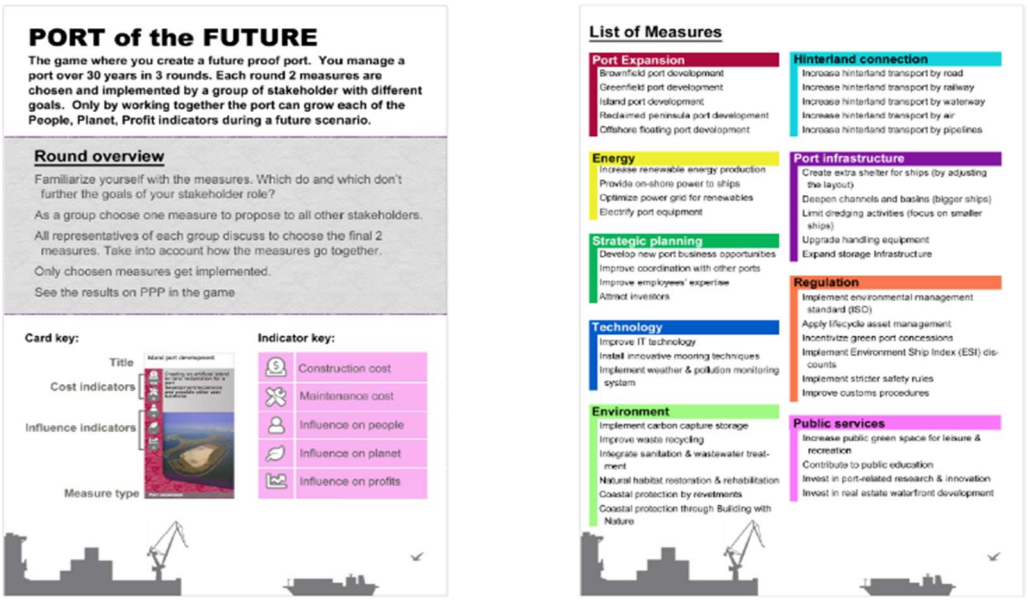

Figure 5 Cheat sheet with a summary of the gameplay on the front-side (left) and a list of categorized measures on the back-side (right).

2.8 Digital simulation environment

The digital component uses the measures selected by the players and events which assorted with a scenario as inputs. It then demonstrates and calculates the effects on the budget and PPP values. The digital screen also displays information on rounds and time. The facilitator can determine the time by manually changing on the screen. A screenshot of the main screen is shown in Figure 6. The port-city is livelier fulfilled with the high-end 3D icons.

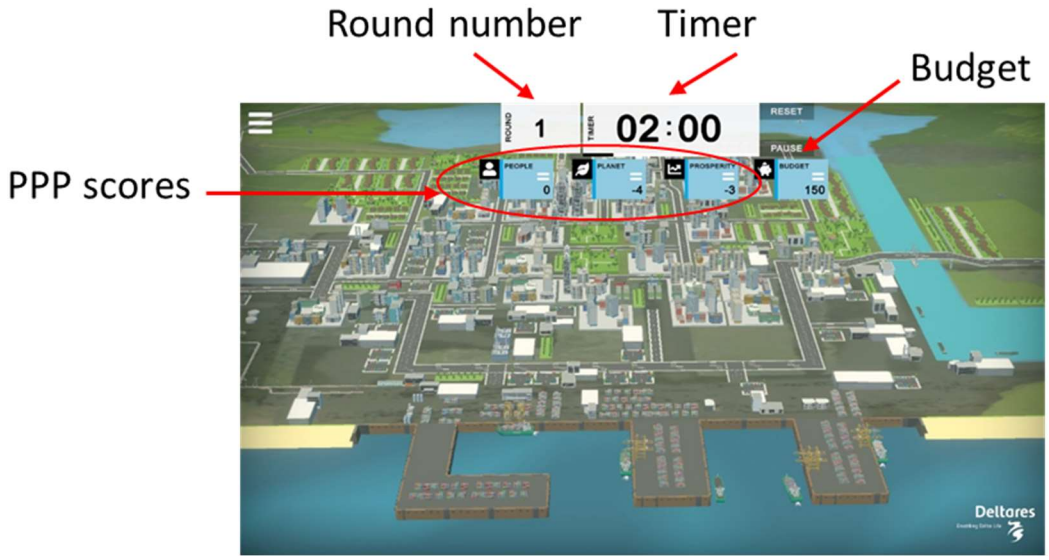

Figure 6 Screenshot of the digital simulation environment with the fictional though realistic port-city landscape.

Once the selection of measures or events confirms, the main screen will zoom in orderly to the locations where the measures or events are implemented. The animated demo of the measures

will be displayed, associated with the PPP values at the bottom of the screen. An example of implementing the measure "integrate sanitation and wastewater treatment" can be seen in Figure 7.

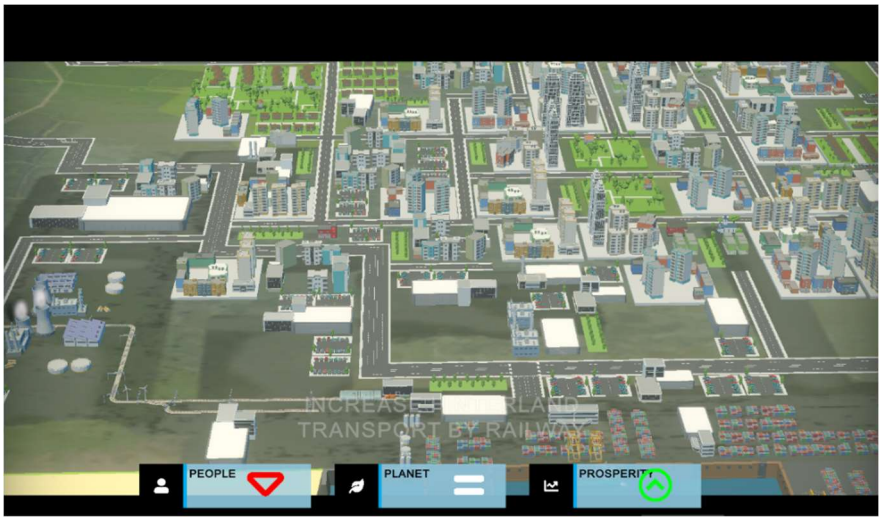

Figure 7 Example visualizing the measure 'Increase hinterland transport by railway' and its effect on PPP scores (green arrow up reflects a positive score, red arrow down a negative score and white equal sign no impact).

According to the scenario that is played, the PPP and budget are set to their appropriate initial values. The algorithm adds the PPP values of each of the two measure cards to the existing overall PPP scores. The result of this summation will be the initial PPP score for the next round. The budget indicates the result of deducted costs and gained benefits in every ten years.

At the end of the game, an end screen displays a screenshot of the initial port and the port after implementing different measures. The values of PPP and budget are compared at the top. An overview of measures and events are listed at the bottom, as shown in Figure 8.

Figure 8 The end screen of the PoFSG showing the comparison between the initial and final scores in terms of People, Planet, Prosperity and budget as well as the selected measures and events.

3. Development approach for PoFSG 2nd edition

The development of the 2nd edition of the PoFSG followed an iterative process (as shown in Figure 9) of three development sprints. First, scoping sessions with COREALIS partners (especially the Living Labs of Livorno, HaminaKotka and Piraeus) and existing users were used to identify the requirements for the 2nd edition. In each sprint, these needs were revised and ranked in order of priority for implementation. Second, the new features with the highest priority were implemented in the PoFSG. Third, benchmarking tests were conducted within Deltares and, after further optimization, during plenary meetings with the consortium partners. Based on the results of the tests, we finetuned and prioritized the requirements with the users. In total we completed 3 iterations of the development cycle: the α1-version (operational game with limited functionalities), the α2-version (all functionalities but not yet fully optimized), and the final version (game as delivered).

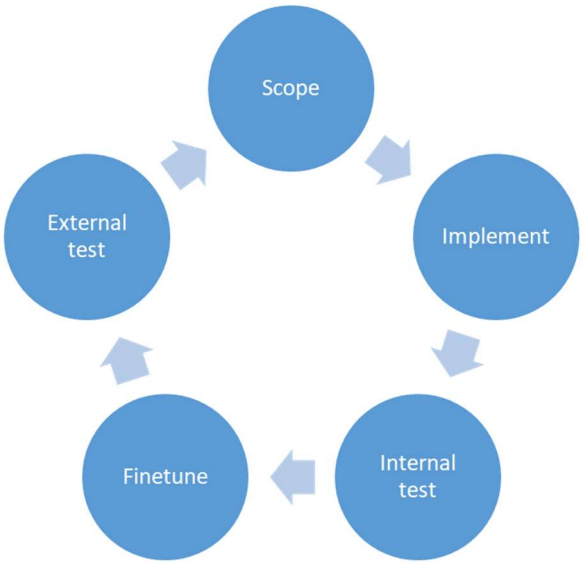

Figure 9 Development process of the PoFSG.

3.1 User and system requirements

The COREALIS partners use a Requirements Traceability Matrix (RTM) in which all requirements from the associated Living Labs (LLs) for each innovation included in COREALIS are combined [5]. Each LL described its current situation and future challenges. Based on their understanding of the game and the challenges of their ports, they expressed their requirements in terms of the simulation environment, game cards, stakeholder roles, measures and customized scenarios to be implemented in the 2nd edition of the PoFSG. From these requirements, we defined a set of "generic user requirements" that describe the generic functionality and can serve all LLs and keep the game versatile (PoFSG_F_GEN_1 and PoFSG_F_GEN_2 in Table 2). Furthermore, the PoFSG has to fulfil specific user requirements from each LL (PoFSG_F_Piraeus_1, PoFSG_F_Livorno_1, PoFSG_F_Livorno_2 and PoFSG_F_HaminaKotka_1 in Table 2) and system requirements based on their scenarios (System_Livorno_Scenario_3_1 and System_PoFSG_HaminaKotka_1 in Table 2). The

following paragraphs discuss how we fulfilled these requirements with the PoFSG and tested them in different versions of the game.

Table 2 Generic requirements for the PoFSG from the COREALIS Requirements Traceability Matrix.

Requirement ID	Title	Description
PoFSG_F_GEN_1	Game rounds and events.	The game must be capable to involve at least 10 different stakeholders, divided in small groups by category (e.g., government, port authorities, financial investors, NGOs and terminal operators). The game will consist of 2-3 different rounds. Each round represents a 10-years period. Stakeholders must choose a game scenario from a range of available scenarios. Each group must select the team captain and decide strategy during the first round for the selected scenario. Stakeholders from each group must select only 2 measures that fit their adopted strategy and reach a common decision. The effects on People-Planet-Prosperity (PPP score) of stakeholders' measures must be measured and displayed within the simulation environment. Unexpected events must be taken into consideration by the game, triggering conflicts and alternative actions from the stakeholders.
PoFSG_F_GEN_2	Interaction between users (stakeholders) and the simulation environment.	The game must provide a wide set of gamecards including different measures in the categories port development/expansion, regulation, cultural services, hinterland connection, logistic capacity, environment, energy systems and strategic planning. The gamecards must have a QR code to be scanned in order to easily insert the measures in the digital environment. The game must give feedback on selected measures in terms of visualization as well as their effects on the PPP scores.
PoFSG_F_Piraeus_1	Impact assessment of the sustainable port-city development.	The game must provide a scenario on sustainable port-city development (including hinterland, mobility as well as the urban connectivity), allowing all involved stakeholders to explore measures in the port-city as well as different hinterland connections by means of gamecards.
PoFSG_F_Livorno_1	Impacts assessment of the investments in emerging technologies (5G).	The game must include measures and events related to innovations for the Port of Livorno (5G) and be able to (qualitatively) assess their potential effects on People, Planet and Profit. Stakeholders must be able to select these measures from a wide range of measures that triggers the users to look at them from different perspectives. The game must be able to drive the stakeholders to the potential benefits and risks of investments in new technologies.
PoFSG_F_Livorno_2	Impact assessment of the climate change adaptation and sustainable port-city development.	The game must allow Port of Livorno stakeholders to explore measures (and related events) for climate change adaptation and sustainable port-city development, including their perspectives. The game must be able to assess the impacts of "green" measures considering both cleaner shipping as well as the usage of LNG filling stations installation.
PoFSG_F_HaminaKotka_1	Measures that facilitate the energy transition.	The game must include measures that facilitate an energy transition scenario, in terms of 1) electrification of machinery 2) using renewable energy 3) plan energy-efficiency measures. The game must allow stakeholders to (qualitatively) assess the potential social, environmental and economic effects of these measures.
System_Livorno_Scenario_3_1	N/A	The PoFSG simulation tool must be able to provide (qualitative) descriptions and visualize information related to the social, environmental and economic costs and benefits of measures (chosen by the Livorno living Lab stakeholders) and events.
System_PoFSG_HaminaKotka_1	N/A	The PoFSG simulation tool should be able to pose dilemmas to the players (stakeholders) tailored to their situation. The HaminaKotka scenario explores what the energy transition could mean to the mid-/long-term port development needs and solutions.

The user and system requirements listed above have been fulfilled in three (internal) development versions of the game in the following order of priority:

α1-version (tested during the plenary in Athens, 27th June 2019):

- PoFSG_F_GEN_1:
  - Different stakeholder roles, game rounds and (new) measures (with fictional scores) were implemented in the game and tested with the consortium partners. Scenarios and events were not yet implemented at that time.
  - The consortium partners indicated that the types of measures and stakeholder roles were fine. However, the scores, costs and benefits were not realistic and, hence, hampered the gameplay. The partners also indicated that stakeholder role cards explaining their roles would benefit the gameplay.
- PoFSG_F_GEN_2:
  - Gamecards were created for the new (categorized) measures where the scores were shown on 9 KPIs instead of 3 PPP scores. The scores were indicated by green (positive) and red (negative) arrows instead of numbered scores, where the number of arrows indicates the magnitude of the effect. Furthermore, QR codes were added to the game cards to insert the measures into the simulation environment.
  - The consortium partners liked the card design and QR codes, but had difficulties understanding all the KPI scores and used the arrows for "book-keeping" in the decision-making process rather than finding convincing arguments for the debate. Therefore, a new way of visualizing the scores on the game cards was developed and tested in the second iteration of the game (see α2-version).
- PoFSG_F_Piraeus_1:
  - Measures for different types of hinterland connections (i.e., by road, railway, waterway, air and pipelines) as well as measures for the port-city (e.g., public services, strategic planning and environmental regulations) were implemented allowing stakeholders to explore ways to achieve sustainable port-city development.
  - The measures were recognized by the consortium partners. However, the scores, costs and benefits were not yet realistic and needed to be updated.
- PoFSG_F_Livorno_1:
  - Technology-related measures (such as 5G) were included in the game.
  - There were some misunderstandings on the level of detail of information that the game provides on the effects of such technologies. It was stressed that the PoFSG is a qualitative awareness-raising game and not a quantitative decision-making tool.
- PoFSG_F_Livorno_2:
  - Measures to support climate adaptation and sustainability in the port (such as renewable energy, carbon capture storage, environmental regulations and coastal protection works) were included in the game.
- PoFSG_F_HaminaKotka_1:
  - Energy-related measures such as renewable energy production, on-shore power supply to ships and electrification were added to the game.

α2-version (tested during the plenary in Valencia, 17th October 2019):

- PoFSG_F_GEN_1:
  - This test version of the game included scenarios and events based on the requirements from the associated LLs (see below). Scenarios and events were tested in an interactive session with the consortium in Valencia and proved to be useful to stimulate debate and (simulated/playfully exaggerated) conflict amongst the different stakeholder roles.
  - Stakeholder role cards were introduced, which helped the players to better fill in their roles and define their related strategies.
  - Based on expert judgment the measures, scenarios and events were scored on the PPP indicators as part of the game development process prior to the game session. The measures were also scored in terms of costs and benefits. The consortium indicated that this made the gameplay much more realistic and effective.
- PoFSG_F_GEN_2:
  - Based on the feedback from the first iteration the measure cards were redesigned. The PPP scores were now indicated only qualitatively on the cards (i.e., "+" for a positive effect, "0" for a neutral effect and "-" for a negative effect). This moved the discussion away from "book-keeping" and made the gameplay livelier. The costs of measures were still expressed in numbers, so that the players can determine whether they have enough budget to "buy" the measures.
- PoFSG_F_Piraeus_1, PoFSG_F_Livorno_1, PoFSG_F_Livorno_2, PoFSG_F_HaminaKotka_1 and System_PoFSG_HaminaKotka_1
  - The specific requirements for the LL scenarios were integrated in the game scenarios and events, complementary to the measures that were already implemented in the first iteration.
- System_Livorno_Scenario_3_1:
  - The simulation environment was made more interactive by better highlighting the effects of measures and events on the PPP scores and budget. This interactive feedback enhanced the learning effect of the players and stimulated them to think differently about measures for subsequent game round.

Final version (tested with the users of the 1st edition in the Netherlands, 5th February 2020):

- The digital simulation environment and game cards were optimized in terms of layout, typos and visual representation of the port-city. The users of the 1st edition indicated that they were happy with both the functionalities that were maintained and those that were new and/or improved.
- 'Cheat sheets' were developed to provide players with an overview of the game rules and measures as a compact reminder document. The cheat sheets were actively used by the players and proved to be helpful in the gameplay.
- As a final step in the game development the documentation of the PoFSG in the form of a user manual (this document) was reported to the consortium and the European Union.

3.2 Stakeholders roles

Stakeholders refer to anyone (or any organisation or company) who is directly or indirectly influenced by the port and its policies, such as the port authority, the residents and NGOs. The game intends to facilitate stakeholder involvement and debate among stakeholders not merely based on the values of each card, but also their distinct and often (perceived) conflicting interests on port development. Therefore, in the gameplay, each team is assigned with a stakeholder role related to port development. This way, 1) the strategy of each team will be more focused, and 2) the debate between the stakeholders (represented by team captains) will be more interesting, as each captain will represent a different consideration or understanding regarding sustainable port development.

For the selection of stakeholder roles in the game, we first did research on multiple types of stakeholders in different ports. Port management and development are influenced by a variety of factors, including society, politic, finance, technology, environment and legislation. Because of these different related factors, many different stakeholders play a role. The stakeholders in port management can be categorized as:

- management stakeholders
- contractual stakeholders
- community stakeholders
- legislation and policy stakeholders
- external stakeholders

In this analysis we have selected the most common types of stakeholders to be included in the game, which are port authority, terminal operator, environmental NGOs, government, local business owner, investor, contractor and shipping company (see Section 2.3). These stakeholders cover all the factors mentioned above. The list of stakeholder roles was reviewed by experts and finetuned based on their feedback.

3.3 PPP indicators

The concept of People, Planet and Prosperity (PPP) plays a key role in the PoFSG to evaluate the decisions of the stakeholders. For each "P", a set of Key Performance Indicators (KPIs) was defined. KPIs have been used for scoring of measurements since these are more specific and interpretable than the more generic and high-level PPP-indicators. This process will be described in detail in Section 3.4.2. Here, we describe how we selected the KPIs.

In the 1st edition of the PoFSG [1] the following KPIs were used at that time:

- People: safety against flooding, employment and well-being;
- Planet: habitat, biodiversity and water quality;
- Profit: port economic growth, fisheries and tourism.

Since then, experience with gameplay and developments in the field of ports have led to other KPIs to be more fitting. Therefore, as part of the 2nd edition of the game we have developed an updated set of KPIs. In the 2nd edition, we retain the three KPIs per sustainable pillar (i.e.,

People, Planet and Prosperity). To find a representative set of KPIs for the ports for each of the pillars, we set the following selection criteria:

1) Each KPI must be sufficiently generic. Similar effects caused by multiple factors must be covered by it and each measure can be scored on it. For example, the indicator 'safety' can cover different threats, such as public safety, flood safety, traffic safety, etc.
2) Each KPI should be quantifiable up to a minimum level. For instance, an indicator that can reflect measurable impacts on employment or port operational efficiency.
3) The set of KPIs should cover indicators for all relevant challenges to the ports, presently and in the foreseeable future, such as those related to climate change and sustainability.

Based on the criteria mentioned above, we made a new set of KPIs, which was reviewed by the COREALIS LLs, users of the existing game and Deltares experts on various fields, such as port operations, ecology, economics, government, etc. In the 2nd edition of the PoFSG the following KPIs are presented as follows:

- People: employment, recreation, safety;
- Planet: environmental quality, climate change mitigation, climate change vulnerability;
- Prosperity: port profit, city-port development, port operational efficiency.

This feedback has been incorporated in the final set of KPIs, which is described detailly in Appendix 1.

3.4 Measures

3.4.1 Port development measures

The key to improve the sustainability performance of a port is combining economic growth with environmental and social considerations. Hence, a balanced range of measures of various aspects of port-city development is important in practice and needs to be available in the serious game. Where the 1st edition (2015) leaned more towards 'green' measures, for the updated game edition we have defined a more balanced set of measures.

To create a new set of measures, we started with a review of the measures in the 1st edition (2015) as well as the user feedback received on those. Generic measures, such as those related to port developments/expansions, hinterland connections and environment, were retained. Other measures were revised or replaced based on the following criteria:

1) Measures being too specific. For example, wind energy is only an example of the types of renewable energy that may be applied in ports.
2) Measures being restricted to specific ecosystems. For instance, 'mangroves' are not applicable for ports outside the tropics.
3) Measures that functionally overlap. For example, 'green roofs on buildings' can be part of 'public green infrastructure'.

To identify relevant new measures, Deltares experts on port operations, hinterland connections, governance, economics, ecosystems and energy transition were asked to identify different aspects and challenges of port-city management, such as infrastructure, organization and auxiliary services. Based on the expert input and literature review, a set of measures was

identified as potential solutions to these challenges. For instance, in terms of port operational efficiency, measures were added that can accelerate the handling and transport of cargo (e.g. upgrade handling equipment and storage infrastructure). When defining measures, we attempted to select "universal" measures that can be applied to most of the ports in the world. The new measure list was sent out to experts from Deltares and LLs representatives for evaluation and review. Finally, their feedback was integrated in the final set of measures. The detailed list of measure is listed in Annex 2.

3.4.2 PPP scores of measures

The measures can be selected and implemented by the players to affect the PPP scores of the port in the game. Therefore, each measure is scored on the nine KPIs that eventually determine the scores on the three Ps. The detailed scores and explanation for each measure are presented in Annex 2. As there are 42 measures and 9 KPIs (hence, 378 combinations to score), fundamental underpinning of all combinations based on a literature review is not feasible. Therefore, the scoring on the KPIs was done through a cross-validated expert judgement process, whereby experts were asked to score and rank the different measures.

First, we provided subsets of 10-15 measures to experts with a wide range of background, including stakeholder engagement, ports, hinterland connectivity, sustainable development, government and socio-economic aspects. Each expert was asked to judge and comment on a subset of measures that was most directly linked to their personal expertise. They assigned scores for all the indicators to the best of their knowledge. Each measure was scored by two experts to reduce bias from different experts, because none of them is an expert on all measures nor on all indicators. Each indicator is scored ranging from -5 to 5, as described in Table 3.

Second, we held an individual interview with these experts to discuss the motivation of the scores. Scores that showed a large difference between expert replies were discussed and adjusted together with experts. The experts also referred us to some references that help explain their choices. For measures which were scored with a significant difference by two experts, for example, one measure is scored positive value by one expert, meanwhile is scored conversely by the other expert, we used additional (objective) sources from literature to come to final scorings.

After having determined the scores of all indicators, the values for each PPP-value was calculated via a normalization method (i.e., using the sum of the 3 KPIs associated to each P normalized by the maximum value of all measures and rescaled on the scale -5 to 5). There are two reasons for choosing this method: 1) the value of each P should be within the range from -5 to 5, so we cannot simply sum up the KPI scores; 2) we would like to maintain some diversity in the scores to give the players something to choose from (e.g., if we simply take the average of the KPI scores, all measures have similar scores, which limits the gameplay). Therefore, we scaled the measures according to their relative impacts compared to each other. The final values for PPP are attempting to provide scores as representative of the real-life situation as possible.

Table 3 Overview of the meaning of (effect) scores on PPP indicators (ranging from -5 to 5).

Score	Effect	Score	Effect
0	No effect	0	No effect
+1	Very small positive effect	-1	Very small negative effect
+2	Small positive effect	-2	Small negative effect
+3	Moderate positive effect	-3	Moderate negative effect
+4	Strong positive effect	-4	Strong negative effect
+5	Very strong positive effect	-5	Very strong negative effect

3.4.3 Costs and benefits of measures

Another criterion for evaluating the performance of strategic decisions is if the selected measures are cost-efficient. Therefore, the game also enforces a financial limitation on the measures.

Each measure card displays a one-time payment for constructing and implementing the measure. The operation/maintenance costs are separate from that and they are deducted in each playing round. The benefits are also added to the port's collected funds in each of the following rounds played. At the beginning of the game, each scenario sets appropriate initial values of PPP and available money for spending. In each round, players select measures in agreement with their stakeholder roles, available funds and the scenario. The digital component of the serious game calculates and displays the combined effects of costs and benefits for the next rounds.

An economist was invited to score the costs and benefits of all measures. As with scoring KPIs of measures, we also took an interview and discussed the underpinning of the scores with the economist. The expert focused on relative costs and benefits, using the most expensive measure as a reference with 100 monetary units.

3.5 Scenarios and events

The development of scenarios and events started from the user requirements from COREALIS LLs. At the time of the COREALIS project, Piraeus LL is interested in a situation associated with hinterland connection and city-port development, Livorno focuses on new technologies, and HaminaKotka requires for the energy transition. Then we asked input from experts to expand the scenarios covering a wide range of crucial 'future' characteristics, such as economic development and climate change. Five configured scenarios plus one flexible neutral scenario was developed. Each scenario assumes a distinctly different direction for the future. Together they describe divergent futures that encompass a significant portion of the underlying uncertainties in the main future challenges. Finally, similar to the measures, PPP values and budgets were scored by experts from Deltares.

3.6 Physical components (game cards)

In the 2nd edition of the game, the measure cards constitute one of the most critical aspects of the serious game, as they give the players the freedom to intervene in the port policy making process and to improve its PPP performance. The purpose of special news cards is to present events and trigger discussion between stakeholders. Based on the feedback from the game users and test sessions, we found that it is necessary to provide cheat sheets and stakeholder cards.

These cheat sheets are one-page flyers that each team receives at the beginning of the game with a summary of the information provided in the game introduction. They are used to remind players about essential information of the game, making it convenient to play. The stakeholder role cards help the players understand their roles.

For designing the 2nd edition of measure cards, we firstly collected feedback from the game users. The most critical feedback was on the inclusion of the PPP values on the cards. This makes the players focussing on bookkeeping of the numbers rather than discussing their strategies. Thus, in the 2nd edition, we resolved the problem by using icons to represent positive or negative efforts of a measure on PPP performance. The development team also created an idea of adding a QR code on the other side of each measure and event card, which provides convivence for the facilitator input the selection into the digital component.

The designs (layout, wording, graphics) of special news cards, cheat sheets and stakeholder cards were also tested internally and externally. And we collected feedback and refined the requirements, such as colours and font of the text.

3.7 Digital simulation environment

The digital simulation environment offers a graphical representation of the hypothetical port and keeps account of the values of the PPP and budget. Similar to the other game elements, we started with feedback collection on the simulation environment of the 1st edition. The feedback indicated that improvements were required on the visualization of the port-city environment and the interactive feedback of implemented measures and events as well as their scores to the players. Therefore, the development of the digital simulation environment aimed particularly on implementing more realistic animations and highlighting the effects on PPP scores and budget. Furthermore, the users indicated that it would be useful to incorporate an evaluation of the game session at the end of the game to highlight the measures and events that were implemented for discussion purposes.

Based on these requirements, the development team designed a new version using a game-engine “Unity”. Alongside the engine, a text editor and a high-end 3D package were used to improve the visualization and interface of the game. The new version was tested with COREALIS partners and with Deltares experts. Then we made the final optimisations to the design, which were tested with existing users of the PoFSG and Deltares experts in a final test session.

4. How to play the game

This chapter describes the game rules and procedures. A game session consists of the following steps: (1) introduction, (2) strategy formation, (3) measure selection and events, (4) discussion on measures between team captains, (5) feedback on the effect of measures and/or events and (6) discussion and conclusions (see Table 4). Steps 2 to 5 are repeated in each game round. The details of each step are described in the following sub-sections.

Table 4 Description of the different playing stages of the PoFSG

Steps	Explanation
1. Introduction	The facilitator presents the game and its objective and explains the storyline of the scenario that is being played. Then, the teams are formed, and the team captains are selected. During this step, the specific roles of stakeholders are assigned to the teams.
2. Strategy formation	The players become familiar with the game and the scenario. Players develop a team strategy to reach the main goals of the game, according to their roles.
3. Game rounds, measure selection and events	In each round, each team selects two port development measures. Measures are selected in agreement with the stakeholder roles and the scenario. After each round, the facilitator can run an unexpected event, which could trigger additional conflict or debate amongst the stakeholders. Subsequently, the players are stimulated to select measures to respond to the event.
4. Discussion on measure selection	After 2 measures are selected by each team, the team captains debate on the final selection of only two measures for all teams. Specific questions can be asked by the facilitator to stimulate the debate.
5. Calculation of the effects of measures	At the end of each round, the digital simulation environment shows the changes in PPP and total budget. The facilitator debriefs with all groups about the outcome, the chosen strategy and the results for the indicators.
6. Discussion and conclusions	The facilitator coordinates an verall debate with the players about the game and its learning effects.

4.1 Introduction

The facilitator starts with a general introduction of the game and its objectives. During the presentation, the facilitator can also ask the players about their expectations or learning goals of the playing session. This exercise is useful for evaluating the success of the game session at the end.

Then the facilitator provides an introduction to a specific scenario storyline in a fictional port context (but based on the challenges of the real-word port development). This storyline in which the facilitator “sets the scene” for the gameplay is important to engage the stakeholders in the gameplay. Examples from real-life ports can be used to illustrate the storylines. However, the fictional port context helps the players to think more out of the box and free from their real-life stakeholder position or role.

Furthermore, the facilitator introduces the rules and procedures of the game as well as the time plan. The facilitator sets the time for the first round, helps to form teams and distributes measures cards, stakeholder cards and cheat sheets.

4.2 Strategy formation

At the start of the game, each team selects a team captain. The responsibility of the captain is to coordinate the team. He/she will also pitch the selected measures to the other stakeholders and debate with the other team captains. The teams spend time on understanding their roles and the measure cards. Then the players develop their basic team strategy to reach the main goals of the game, according to their roles.

4.3 Game rounds, measure selection and events

Each team selects two development measure cards in each round. Measures are selected in agreement with the stakeholder roles and the scenario. At the beginning of the 2nd and 3rd rounds, the facilitator runs an unexpected event by displaying the fictional newspaper and explaining the relevance of this event within the scenario. Then the facilitator sets a new timer indicating the game time available for the next round. Players can again select two other measures according to their stakeholder roles and the changed PPP values. It is stressed that the measures that have been applied in the previous rounds remain effective for the rest of the game and their operation/maintenance costs and benefits are accumulated in each round automatically by the digital game environment. For this reason, and to stimulate gameplay dynamics, measures cannot be selected twice.

4.4 Discussion, negotiation and measure selection

After each determines its selection of the two measures, team captains debate on the final selection of only two measures for all teams. During the debate, the facilitator can answer some specific questions and help captains to reach a consensus. The facilitator debriefs about the outcome, the chosen strategy and the results for the indicators.

4.5 Calculation of the effects of measures

The final step of each round is inputting the choice of measure cards into the game. The digital simulation environment calculates scores of PPP and budget. The instruction of using the digital part can be found in Appendix 3. After clicking the confirm button for next round, the system automatically calculates the effect of the two measures on PPP and budget.

4.6 Discussion and conclusions

After the completion of the three rounds, a review of the three rounds is presented on the screen. The facilitator gives players the opportunity to discuss with each other the selection of measures, the solutions to the unexpected event and their strategic decisions. The focus lies on the lessons learned regarding the real-world challenges and on the future opportunities for the port.

Then players are invited to fill out the serious game questionnaire. It can provide useful input for the game developers and the facilitator as far as the optimisation of the serious game and the workshop are concerned.

5. Facilitating the game

The success of a PoFSG workshop depends to a large extent on the facilitator. The facilitator should set the scene, encourage players to think and act differently, reflect on the choices that were made and stimulate discussion and learning. This chapter is meant to give some hints to the facilitator that will help to make a game session successful.

5.1 Preparation for the playing workshop

Before the gameplay, the facilitator needs to make adequate preparation for the playing session. The facilitator starts with an interaction with the organizer. The facilitator introduces the desired number of attendants and time and makes requests on facilities, such as the setting of the room and beamer. The organizer provides information on the challenges of the port and invited stakeholders. Then, together with the hosting organisation, the facilitator selects a scenario and appropriate stakeholder roles for the workshop and prepares an introductory presentation to set the scene of the gameplay.

5.2 Facilitating the game

During the introduction, the facilitator has to set the scene for the players. On the one hand, the scene must be general without giving too much subsistent information on the case they are going to play. For example, the facilitator can describe a port without mentioning the name or using a fictional name. From the facilitating experience of the 1st edition, we know that in some cultures, mentioning subsistent information may make players feel uncomfortable and stick to their real stakeholder role rather than stepping out of it. On the other hand, the scene must include case-specific elements related to the selected scenario. For instance, in the scenario of the energy transition, the scene can be described as a port combating climate change with the ambition to play a leading a role in the global energy transition.

During the game rounds, the facilitator must always keep time. While the players are selecting measures, the facilitator can walk around, ask players questions, ask about their strategies, give an explanation on measures, and give some hints, such as the benefits that can be gained through the rounds.

In the discussion and debating stage, the facilitator can answer some specific questions and help captains to reach a consensus. The consensus can be reached via different approaches described as follows:

1) Majority rules: suggesting captains choose the cards which are selected by more than one stakeholder team.
2) Negotiating settlement: the facilitator can remind the captains about negotiating conditions for subsequent rounds.
3) Democratic consultation: let all participating stakeholders vote about the selection.

It is worth noting that the approaches mentioned above are just for reference; the facilitator is free to create various methods to let the stakeholders reach consensus. For example, the facilitator can also involve the audients to challenges captains, if he/she thinks it would help for the debate.

Once the final two measures are selected, the facilitator debriefs about the outcome and the chosen strategy to the players. Then the facilitator runs the digital simulation environment to show the results for the indicators. During and after the animation of measures or events, the facilitator should catch the attention of the players about the effects on PPP and/or budget on the screen and highlight/explain the changes in scores.

5.3 Closure of the game workshop

During the closure of the playing session, the facilitator can discuss with the players on three major points as follows:

1) the lessons learned from the gameplay;
2) the opportunities for the port development;
3) feedback on the game experience.

The discussion on the lessons learned will focus on understanding the concept of sustainability and different stakeholder viewpoints on the port. The players can share their strategic decisions on the scenario and events, their selection of measures and the outcome of the game. The facilitator can also provide a comparison of the wishes that players drew at the beginning of the playing session. Finally, the facilitator can lead the stakeholders to analyse their local challenges, opportunities and relevant processes.

6. More game information

For more information on the PoFSG, acquiring the game or arranging a workshop, please contact Deltares via: https://www.deltares.nl/en/software/port-of-the-future-serious-game/.

More information on the COREALIS project can be found via: https://www.corealis.eu/.

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Annex 1: Background information on PPP and KPIs

The aim of indicator selection in this game is to represent as effective as possible the policy-making process in a fictional port. The main categories of each PPP aspect and their underlying KPIs were defined iteratively in interaction with the LLs and present game users. Based on those discussions we have come to the conclusion that the pillar of 'Profit' (from the original game version from 2015) should be replaced by 'Prosperity', to represent all kinds of economic benefits of port city areas. That new pillar is divided into 'port profit', 'city-port development' and 'port operational efficiency'. The alternative indicators for all 9 KPIs in the 2nd game edition are described in the following subsections.

A1.1 People

A1.1.1 Employment

The creation of new jobs is a crucial criterion for evaluating the social performance of each measure. Measures consisting of different forms of port development can create new jobs which are directly related to port activities or indirectly related to other businesses linked to port activities. Automation may lead to declines in the traditional job market.

A1.1.2 Recreation

'Recreation' is defined as the creation of spaces or infrastructure for cultural and recreational activities in the port-city area. The recreation indicator can reflect the well-being of residents and provide policymaker with a united measuring index to quantify. The indicator can be evaluated with 1) the space of cultural and recreational services and activities, such as beaches, surfing, sailing, museums and tours; 2) tourism opportunities, for example, creating more accommodations and cruise terminals.

A1.1.3 Safety

In the serious game we use a more general term 'Safety'. In this way, we can evaluate the indicator with levels of threats to people's life due to multiple factors, such as extreme weather condition and shipping accidents, as well as the levels of capacity to deal with unexpected safety-related natural or human-made events, for instance, storms or oil spills.

A1.2 Planet

A1.2.1 Environmental quality

We use the indicator of 'Environmental quality' to represent all parameters related to environmental quantity and quality in the port and its surrounding areas. This indicator consists of (air, water, soil and noise) pollution, quantity or areas of natural resources, and nature conservation or compensation measures initiated by the port.

A1.2.2 Climate change mitigation

Climate change mitigation has received more attention in the port community [6] mainly due to the significant share of CO_2 emissions from ships at berth [7]. For this reason, every policy measure should be assessed regarding climate change mitigation. This indicator is evaluated by

considering if a measure increases facilities for and use of renewable energy resources, increases green space and conservation or includes rehabilitation of ecosystems.

A1.2.3 Climate change vulnerability

Port-city areas are likely to be one of the most vulnerable to climate change because they are located in areas exposed to sea-level rise, climate-related extreme weather events, such as storms, droughts and floods. To remain efficient and resilient, the port-city combination must anticipate the impacts of climate change and prepare for decreasing its vulnerability to those foreseen changes by:

- Reducing the probability of the port-city to be impacted by a hazard via, for example, moving activities where possible to higher areas, or build protection measures.
- Reducing the potential consequences of hazards. For instance, educate residents in port-city areas about climate change, build escape routes, and optimize the planning of assets.
- Allowing for flexibility in dealing with climate-related changing conditions [8].

A1.3 Prosperity

A1.3.1 Port profit

Port profit represents direct economic benefits to the port, and competitiveness in the global transport market. This indicator is evaluated with the changes in throughput, market share and other port-related economic benefits, such as logistics and auxiliary services.

A1.3.2 Port-city development

As ports expand, they can have many effects on cities, negatively increasing possible traffic congestion in the city, or positively promote local business development. Therefore, any discussion that is associated with the Prosperity of a measure should take into account the impact it has on city-port interactions and interdependencies.

A1.3.3 Port operational efficiency

Another indicator of Prosperity concerns the direct benefit created by a better management on maritime shipping, terminal operation including mooring and offloading of vessels and logistic services. This indicator can represent single or multiple criteria, such as turnabout time, handling efficiency, spacing and timing of cargo storage, and hinterland connectivity.

Annex 2: Measure scores on PPP indicators and budget

This appendix provides the descriptions of the measures, their scores on the Key Performance Indicators (KPIs, see Annex A1) and People Planet and Prosperity (PPP) as well as their costs and benefits. There are 42 measures available in the serious game, which were all scored on 9 KPIs by means of expert judgment. Each indicator is scored on a scale from -5 to 5 (ranging from a very strong negative to a very strong positive effect). These scores are indicative and are used to indicate the *relative* effects of measures. Hence, the measures with the most positive impact on a KPI obtain the highest score of 5. Subsequently, the other measures are scored relative to this maximum score.

The costs of the measures are assigned on a range from 0 to 100 monetary units. The measures with the highest (implementation) costs obtained the maximum costs of 100. Subsequently, the implementation costs of the other measures have been estimated relative to these maximum costs. Apart from the implementation costs (which are only charged once, similar to CAPEX), each measure has maintenance and/or operation costs which are returning each round (similar to OPEX). In specific cases the maintenance/operation costs can be negative, which reflects a cost saving during the operational lifetime of the measure. For example, 'upgrading port equipment' can reduce the maintenance costs compared to an aging/older generation of equipment. The differences in the costs between the measures are primarily determined by the relative size of the measure as well as their complexity (which can refer to the technical complexity of the measure itself or the environment in which it is implemented). As the port development/expansion and infrastructural measures are generally both the largest in size and the most complex to implement, those have the highest implementation and maintenance costs. The costs of the other measures are determined relatively to these "big" measures.

Furthermore, each measure has a benefit function that reflects the income that is generated by the measure in time. Figure 10 provides a typical example of the resulting net benefits (i.e., sum of costs and benefits) as a function of time. The net benefit function describes how the income generated from the measures tends to be a bit lower just after its implementation (i.e., start-up costs) and then increases in time. At some point, the net benefits may decrease again towards end-of-lifetime (due to aging equipment and/or efficiency losses, not shown in Figure 10). Depending on the number of rounds that is played, the return on investment (if any) may not be materialized when the game is shorter, or a measure is implemented later in the game.

In the lists below we provide the cumulative net benefits (reflecting the sum of the income and the costs) after four playing rounds (reflecting roughly 40 years). That value is mentioned between brackets behind each element.

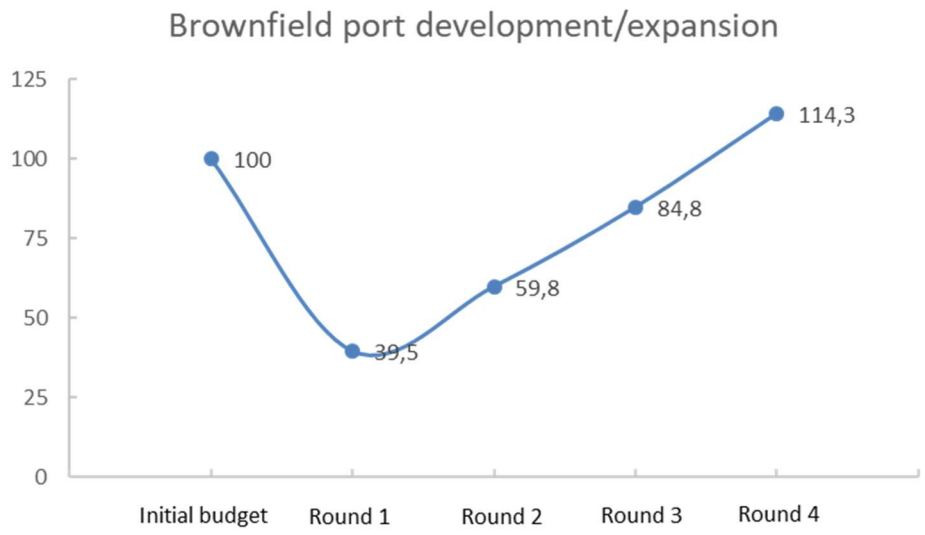

Figure 10 Example of how the benefits of a measure develop over time.

A2.1 Category 1: Port development or expansion (total 5 measures)

A2.1.1 Brownfield port development/expansion

Definition: port development or expansion by revitalizing an (underused) old industrial area.

Table 5 PPP scores, costs and benefit of brownfield port development/expansion.

Construction			**Maintenance**			**Operation**			**Total benefit**
70			**4**			**2**			**90**
People 3			**Planet 0**			**Prosperity 3**			
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency	
3	1	0	1	0	0	5	2	1	

- **People (3):** A port development or expansion creates job opportunities [9]. Furthermore, this measure can free up space for recreation, which was occupied by the old industrial area.
- **Planet (0):** The port development is not expected to have a net positive or negative effect on the environment as the port development replaces an old industrial area, which is assumed to have an environmental footprint as well. Only environmental quality is expected to improve slightly due to stricter environmental regulations and better land management nowadays compared to what may have been applied to the old industrial area.
- **Prosperity (3):** This measure enlarges the port's capacity, which increases the revenues for the port. Due to the installation of new equipment, also the port efficiency is expected to increase. The city nearby will also benefit from the increasing (tax) income and job opportunities for residents.
- **Implementation costs (70):** Port development or expansion will have high implementation costs, because of high costs for preparing the area, construction materials and labour.

- **Maintenance costs (4):** A larger port requires relatively high maintenance costs to keep the infrastructure and equipment up to standard.
- **Operation costs (2):** The operational costs (e.g., traffic management, security, customs) are estimated to be lower than the maintenance costs.
- **Benefits/income (90):** The increased port capacity is expected to lead to a return on investment on the mid- to long-term (NB: note that this return on investment may not be materialized when the game is shorter, or the measure is implemented later in the game).

A2.1.2 Greenfield port development

Definition: Port development or expansion on an unused area, presently without any infrastructure or economic activities.

Table 6 PPP scores, costs and benefit of greenfield port development

Construction	Maintenance	Operation	Total benefit
70	4	2	90

People			Planet			Prosperity		
1			-3			5		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
4	-2	-1	-4	-5	1	5	5	2

- **People (1):** Although a green field port development will create major economic activities and job opportunities (compared to the situation before), the port development requires space at the expense of other functions (perhaps recreation). The greenfield port development may also lead to other adverse effects such as possible relocation of people and port-induced erosion.
- **Planet (-3):** Compared to other expansion options available within the game, the replacement of an undeveloped area is expected to result in overall very negative environmental impacts in terms of environmental quality (e.g., habitat loss) and related to climate change. On the other hand, the greenfield is likely to be subject to higher climate change adaptation standards. Therefore, the score on climate change vulnerability is slightly positive.
- **Prosperity (5):** This measure is likely to have a very positive effect on the port prosperity, especially in terms of port profit and port-city development. Because of the new port development or expansion, the port will stimulate infrastructure development in, road/rail connection to and economic activities in the city.
- **Implementation costs (70):** Similar to other port development or expansion measures, the implementation costs for greenfield developments are high.
- **Maintenance costs (4):** The maintenance costs to keep the infrastructure and equipment up to standard are similar to other port development/expansion measures
- **Operation costs (2):** The operational costs (e.g., traffic management, security, customs) are estimated to be similar for most port developments.

- **Benefits/income (90):** The increased port capacity is expected to lead to a return on investment on the mid- to long-term (NB: note that this return on investment may not be materialized when the game is shorter, or the measure is implemented later in the game).

A2.1.3 Island port development

Definition: Creating an artificial island by land reclamation for a port development or expansion and possibly other user functions.

Table 7 PPP scores, costs and benefit of island port development

Construction			Maintenance			Operation			Total benefit
100			2			2			79
People 3			Planet -3			Prosperity 3			
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency	
3	2	-1	-2	-4	-2	4	2	1	

- **People (3):** The overall effect on people is likely to be positive. Compared to greenfield and brownfield port developments, the size of the island is likely to be smaller. Thus, the score on employment is slightly lower. However, the new island could also create space and opportunities for recreation. The island expands towards to sea, which will negatively influence (coastal) safety.
- **Planet (-3):** The overall effect on planet is considerably negative. The scores on all the environmental indicators are negative, because the artificial island interferes with the coastal ecosystem, stimulates port activities with associated greenhouse gas emissions and expands seaward which makes it potentially more vulnerable to climate change [10].
- **Prosperity (2):** Port development on an artificial island near the port means an increase in the port capacity, leading to increasing profit. It also means that additional operational measures will be necessary for transporting the cargo from the island to the main port area [11]. An island located in deeper water may mean less dredging requirements to allow deep-draught vessels to visit the port facilities.
- **Implementation costs (100):** Building an artificial island is the most expensive measure due to its superior difficulty.
- **Maintenance costs (2):** The relatively smaller size requires less maintenance costs than the greenfield and brownfield port developments. Attention is required to infrastructure being more exposed to the ambient conditions (e.g. wave impacts).
- **Operation costs (2):** The operational costs (e.g., traffic management, security, customs) are estimated to be similar for most port developments.
- **Benefits/income (79):** Due to limitations in size and onshore logistics, the large implementation costs of a port island are not expected to be earned back soon.

A2.1.4 Reclaimed peninsula port development

Definition: Port development or expansion on an artificial peninsula by land reclamation.

Table 8 PPP scores, costs and benefit of reclaimed peninsula port development.

Construction			Maintenance			Operation			Total benefit
90			2			2			94
People 3			Planet -2			Prosperity 3			
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency	
3	2	-1	-2	-4	0	4	2	1	

- **People (3):** The measure provides similar benefits for society as the island port developments. Both measures are expected to have a positive effect on the employment and offer space for recreational activities. However, flood safety could be a point of attention.
- **Planet (-2):** The measure provides similar benefits for the environment as the island port development measure. However, a peninsula creates an artificial defence for the existing port from the climate-related hazards. On the other hand, the peninsula itself may require extra coastal protection. Therefore, the positive and negative effects of the peninsula on climate change vulnerability may be balanced.
- **Prosperity (3):** The measure provides similar benefits for the economy as island port development.
- **Implementation costs (90):** Building a peninsula is expensive, due to the costs for land reclamation (but slightly less than an island which requires even more dredging efforts).
- **Maintenance costs (2):** Because this expansion has a direct connection to the existing port facilities and areas, and may therefore be less complex to maintain, this measure involves less maintenance cost than the previous measures.
- **Operation costs (2):** The operational action is relatively simple compared with other port operational activities.
- **Benefits/income (94):** The implementation costs for a reclaimed peninsula are high, but it also leads to increased port capacity that can benefit from the existing hinterland connections and logistics. Therefore, this measure is expected to result in a small return on investment after 4 rounds (~40 years). (NB: note that this return on investment may not be materialized when the game is played for less than 4 rounds, or the measure is implemented later on into the game).

A2.1.5 Offshore floating port development

Definition: Installing floating port facilities for loading and unloading off the coast.

Table 9 PPP scores, costs and benefit of offshore floating port development.

Construction	Maintenance	Operation	Total benefit
50	2	3	59
People 1	Planet -2	Prosperity 2	

Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
3	0	-2	-1	-3	0	3	2	-1

- **People (1):** Offshore floating facilities contain a similar function as an artificial island in terms of employment. However, due to their location in harsher conditions, offshore floating facilities require additional attention to safety.
- **Planet (-2):** Although the port development/expansion will stimulate port activities that are likely to increase greenhouse gas emissions, the floating infrastructure will be less harmful to the environment than most of the other port development measures.
- **Prosperity (2):** As offshore floating facilities are often smaller than the other types of port developments, its effect on profit is (slightly) smaller size on profit. Furthermore, offshore infrastructure will face harsher natural conditions and require extra logistics from offshore to land compared to the other port development measures [12]. This could reduce the port's operational efficiency.
- **Implementation costs (50):** Because of its size, the implementation of offshore floating facilities is expected to be cheaper than other development measures.
- **Maintenance costs (2):** The relatively smaller size requires less maintenance cost than the other port development measures. The mooring structures of the floating areas will be critical so the design should ensure limited risks and maintenance.
- **Operation costs (3):** The operational costs are likely to be higher, due to its remote location which requires additional logistics and safety measures.
- **Benefits/income (59):** Due to its smaller size this measure will result in lower benefits than the other port development/expansion measures. The more distant location will mean larger logistical costs. Overall, the return on investment is expected to be positive.

A2.2 Category 2: Hinterland connection (total 5 measures)

A2.2.1 Increase hinterland transport by road

Definition: Invest in road connections to increase hinterland transport capacity (e.g., expansions or new roads).

Table 10 PPP scores, costs and benefit of increased hinterland transport by road.

Construction			**Maintenance**		**Operation**	**Total benefit**		
40			**4**		**4**	**37**		
People 0			**Planet -3**			**Prosperity 1**		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
4	1	-4	-3	-3	-1	1	1	1

- **People (0):** The overall effect on people is expected to be neutral. On the one hand, additional road capacity is expected to be positive for employment (i.e., trucks are relatively labour intensive) and commuting. On the other hand, road safety may be at stake.

- **Planet (-3):** The effects on the planet are expected to be negative. Road transport is generally associated with high emissions of greenhouse gasses and other toxic substances affecting the environmental quality [13].
- **Prosperity (1):** The road connections are expected to have a mildly positive effect on the port prosperity due to improvement in the logistic value chain of the port.
- **Implementation costs (40):** Infrastructure investments, such as road construction, are often rather expensive. However, the implementation costs are expected to be lower than those of port development/expansion measures.
- **Maintenance costs (4):** As all infrastructure, roads require regular maintenance costs to keep the road in good condition.
- **Operation costs (4):** Increase road capacity will also lead to increased operational costs in terms of, for example, traffic management, (speed limit) law enforcement and custom control.
- **Benefits/income (37):** Due to the shift to alternatives modes of transport (with lower CO_2 emissions) it is questionable whether investments in roads will be earnt back.

A2.2.2 Increase hinterland transport by railway

Definition: Invest in railway connections to increase hinterland transport capacity (e.g., expansions of existing routes or new railways).

Table 11 PPP scores, costs and benefit of increased hinterland transport by railway.

Construction			Maintenance			Operation		Total benefit
60			1			1		64
People			Planet			Prosperity		
-1			0			2		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
1	0	-3	-1	1	0	2	1	1

- **People (-1):** The overall effect on people is expected to be slightly negative. Similar to road connections, railway connections can lead to safety challenges, e.g. related to transport of toxic materials. For railway connections, these negative effects on safety are not counter-balanced by a major increase in employment (since it is not as labour intensive as truck driving).
- **Planet (0):** The overall effect of railways is expected to be neutral. The rail infrastructure itself as well as the noise will have a somewhat negative effect on the environmental quality, but the effect on greenhouse gas emissions is expected to be positive, especially if electricity is used from renewable sources. These effects have been assumed to cancel each other out.
- **Prosperity (2):** Increased transport capacity by rail is expected to benefit the port profit and efficiency.
- **Implementation costs (60):** The implementation costs for railways are often higher than those of road due to the additional (traffic) safety systems and supporting infrastructure and equipment (such as crossings and electrical installations).

- **Maintenance costs (1):** The maintenance costs are expected to be slightly lower than those of roads.
- **Operation costs (1):** As traffic safety management is to large extent automized, railways are expected to have relatively low operational costs.
- **Benefits/income (64):** Railways are expected to result in a return on investment after several years of operation.

A2.2.3 Increased hinterland transport by waterway

Definition: Invest in waterway connections to increase hinterland transport capacity (e.g., wider, deeper or new waterways).

Table 12 PPP scores, costs and benefit of increased hinterland transport by waterway.

Construction	Maintenance	Operation	Total benefit
40	1	3	56

People			Planet			Prosperity		
1			0			3		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
1	0	0	0	3	-2	3	1	3

- **People (1):** Waterways are expected to result in a small positive effect on people in terms of employment. In general, if the traffic control of waterway is managed properly, it does not lead to major safety challenges (compared to roads and railways).
- **Planet (0):** The effects on the planet are expected to be neutral. Inland waterway transport is environmentally friendly with a substantially lower CO_2 emission per tonne-kilometer than transport by road or railways [14]. However, water levels (and therewith available water depths to accommodate vessel drafts) can fluctuate much. This may become more outspoken in the future because of climate change [15]. In the case of low water levels, less cargo can be transported with inland ships due to drought restrictions, which makes waterway connections more vulnerable to climate change [15].
- **Prosperity (3):** The port will profit from the increased logistical efficiency and low costs of transportation.
- **Implementation costs (40):** Infrastructure investments such as waterways, require large implementation costs, similar to those of road connections.
- **Maintenance costs (1):** Generally, the maintenance (dredging) costs of waterways are low compared to road connections, but this is of course depending on the local situation.
- **Operation costs (3):** Operational costs in terms of operations of bridges and locks are generally slightly higher than for the other modalities.
- **Benefits/income (56):** Overall, investments in waterway connections tend to have a large return on investment.

A2.2.4 Increased hinterland transport by air

Definition: Invest in air connections effectively to increase hinterland transport capacity (e.g., by planes or drones).

Table 13 PPP scores, costs and benefit of increased hinterland transport by air.

Construction			Maintenance			Operation		Total benefit
60			4			6		22
People 1			Planet -2			Prosperity 1		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
2	0	-1	-1	-5	0	1	1	1

- **People (1):** Transport connections through the air tend to have a slightly positive effect on people, mainly due to increased employment opportunities due to the required auxiliary services. Note that negative effects such as noise are considered in relation to environmental quality (Planet).
- **Planet (-2):** The effect on the planet is expected to be negative, especially due to significant increases in CO_2 emissions, but also due to decrease of environmental quality in terms of noise and air pollution.
- **Prosperity (1):** Firms requiring good access to distant markets have sought sites to airports. Thus, the link between manufacturing and ports by air can contribute to the growth of port-city prosperity.
- **Implementation costs (60):** Building new airport costs more than road and waterway expansion, because of high costs for preparing the area, construction materials and labour.
- **Maintenance costs (4):** Airport is sensitive to natural conditions, for example, strong winds or fog conditions forces an airport to close down. The weather conditions cause additional expenses for crew and aggravate preparatory and maintenance ground work, such as de-icing and more time required for fuelling and loading [16].
- **Operation costs (6):** The operation costs are higher than maintenance costs, because the complexity and safety challenges, it requests more operational adjustment [17].
- **Benefits/income (22):** Due to limitations in logistic capacity/frequency and high operation costs, the big implementation costs of roads are not expected to be earned back soon.

A2.2.5 Increase hinterland transport by pipelines

Definition: Invest in pipeline connections to increase hinterland transport capacity (e.g., by building new pipelines).

Table 14 PPP scores, costs and benefit of increased hinterland transport by pipelines.

Construction			Maintenance			Operation		Total benefit
25			1			1		30
People 1			Planet 1			Prosperity 1		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
1	0	1	2	0	0	1	1	1

- **People (1) & Planet (1)**: Pipelines offer a safe and environmentally-friendly transport solution by transporting liquid bulk without visible activities on the surface. Pipelines create a few job opportunities for maintenance and operation.
- **Prosperity (1):** Pipeline network can not only create an active integration within the port but also build interaction with industries and clusters in the hinterland and neighbouring ports.
- **Implementation cost (25):** Building pipelines costs more than road and waterway expansion, because the complexity of construction work (e.g. drilling or trenching), special construction materials and labour.
- **Maintenance costs (1):** Due to its unexposed design to the natural environment, the maintenance costs are the lowest in the category of hinterland connectivity. Maintenance of pumps of boost stations and pipelines will be an attention point.
- **Operation costs (1):** The operational costs (e.g., traffic management, security, customs) are expected to be low, because of its unexposed design to the natural environment.
- **Benefits/income (30):** This measure results in a return on investment after several years of operation.

A2.3 Category 3: Energy (total 4 measures)

A2.3.1 Increase renewable energy production

Definition: Increase the use of renewable energy resources such as wind, solar or hydro-power, instead of using fossil fuels.

Table 15 PPP scores, costs and benefit of increased renewable energy production.

Construction			Maintenance			Operation			Total benefit
8			1			1			11
People 1			Planet 3			Prosperity 2			
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency	
2	0	0	2	5	0	2	2	0	

- **People (1):** The effect on people is positive due to increasing employment.
- **Planet (3):** The impact on "planet" is positive as the growth of clean energy, which reduces the levels of GSG emissions.
- **Prosperity (2):** Selling the renewable energy that is generated will generate income. The improved environment will also benefit for port-city relationship.
- **Implementation costs (8):** Within the energy category, this measure requests more constructive activities, for building associated infrastructure such as wind farm or solar panels.
- **Maintenance costs (1):** The costs are low because most of these developments do not require constant maintenance and more focused repair and servicing actions can be applied.
- **Operation costs (1):** The operation requests only a few labourers, thus, the costs are expected to be low.
- **Benefits/income (11):** This measure results in a return on investment after several years of operation.

A2.3.2 Provide on-shore power to ships

Definition: Use onshore electrical power supply for moored vessels as an alternative to onboard fuel-based power generation.

Table 16 PPP scores, costs and benefit of provide on-shore power to ships.

Construction	Maintenance	Operation	Total benefit
5	1	-	7

People			Planet			Prosperity		
1			2			0		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
1	0	0	1	3	0	1	0	0

- **People (1):** The new action requires hiring a few professional technicians, so this generates jobs.
- **Planet (2):** Providing an onshore power for ships at berth can result in critical environmental gains. CO2 emissions are reduced substantially, and the emission of sulphur dioxide and nitric oxide decreases [18].
- **Prosperity (0):** Selling electricity will generate a small amount of profit.
- **Implementation costs (5):** Within the energy category, this measure requests less constructive activities than building renewable energy.
- **Maintenance costs (1):** The maintenance cost is low because of easy access to the installation and a limited number of moving parts.
- **Operation costs (-):** Once installed, the measure does not require large operational actions by the port authority.
- **Benefits/income (7):** This measure results in a return on investment after several years of operation.

A2.3.3 Optimize power grid for renewables

Definition: Optimize the power grid infrastructure to deal with peaks and drops in renewable energy supply (e.g., using batteries or other forms of energy storage).

Table 17 PPP scores, costs and benefit of optimize power grid for renewables.

Construction	Maintenance	Operation	Total benefit
5	1	-	7

People			Planet			Prosperity		
1			1			1		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
1	0	0	1	2	0	0	1	1

- **People (1):** The new action requires hiring a few professional technicians, which results in jobs.

- **Planet (1):** This measure can also reduce greenhouse gas emissions.
- **Prosperity (1):** Optimization of power grid improves power supply reliability and efficiency, which is essential for the port operation and city communities.
- **Implementation costs (5):** Within the energy category, this measure requests less construction activities than building renewable energy.
- **Maintenance costs (1):** the maintenance cost is low because it only requests maintenance in certain periods.
- **Operation costs (-):** the measure does not require any operational action.
- **Benefits/income (7):** This measure results in a return on investment after several years of operation.

A2.3.4 Electrify port equipment

Definition: Electrify port equipment such as vehicles, cranes, straddle carriers, stackers and robots.

Table 18 PPP scores, costs and benefit of electrify port equipment.

Construction			Maintenance			Operation			Total benefit
8			-1			-1			14
People 2			Planet 2			Prosperity 1			
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency	
1	0	2	2	3	0	1	0	1	

- **People (2):** The new action requires hiring a few professional technicians. This option markedly contributes to a more secure operation.
- **Planet (2):** This measure can also reduce greenhouse gas emission by partly replacing fossil-fuel usage in the port.
- **Prosperity (1):** The port authority or other party providing this service can benefit from selling the electricity.
- **Implementation costs (8):** This measure requires supporting construction in the port, which costs more than other measures within the energy category.
- **Maintenance costs (-1):** The maintenance costs reduce compared to fossil fuel usage, which costs more on maintenance work [19]. Battery life and replacement of such parts will require attention.
- **Operation costs (-1):** Same as maintenance costs, the operational costs also reduce due to the electric usage.
- **Benefits/income (14):** This measure results in a return on investment after several years of operation.

A2.4 Category 4: Port infrastructure (total 5 measures)

A2.4.1 Create extra shelter for ships (by adjusting the layout)

Definition: Construct breakwaters or similar structures to provide improved shelter to ships for waves and currents and enable safer navigation and port operations.

Table 19 PPP scores, costs and benefit of create extra shelter for ships.

Construction			Maintenance			Operation		Total benefit
4			0.5			-		7
People 1			Planet 1			Prosperity 2		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
0	0	1	-1	1	3	2	0	3

- **People (1):** The decreased wave activity within the port can increase the defence capability of a flood, which increases the safety of the port.
- **Planet (1):** The main drawback of this measure is the change of the original water environment and ecosystem. However, the decreased wave activity within the port improves defence capability of extreme climate-related events.
- **Prosperity (2):** The more effective navigability of ships in the port and vessel moored under more tranquil conditions at berth (smaller vessel motions and therefore more effective (off)loading) leads to a positive effect on profit and operational efficiency [20, 21, 22].
- **Implementation costs (4):** This measure will be implemented with smaller constructive actions than if also including a reclamation.
- **Maintenance costs (0.5):** The maintenance costs to keep the infrastructure up to standard.
- **Operation costs (-):** This measure does not require any operational activity.
- **Benefits/income (7):** This measure results in a return on investment after several years of operation.

A2.4.2 Deepen channels and basins (to receive bigger ships)

Definition: Deepen the port access channels and basins by dredging to facilitate bigger ships to safely navigate and berth in the port.

Table 20 PPP scores, costs and benefit of deepen channels and basins.

Construction			Maintenance			Operation		Total benefit
10			1			-		15
People 1			Planet -2			Prosperity 3		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
1	0	1	-3	-1	-1	3	1	4

- **People (1):** Bigger vessels lead to a positive effect on employment. Infrastructure better tailored towards a specific size of vessels is expected to lead to an increase of operational safety.
- **Planet (-2):** Dredging activities affect water turbidity. A larger water depth promotes salt intrusion into connection estuaries and rivers.
- **Prosperity (3):** The dredging activities leads to intensified marine traffic which results in positive impacts on port prosperity.
- **Implementation costs (10):** This measure will be implemented with more constructive actions than other measures within the category.
- **Maintenance costs (1):** The maintenance costs consist of costs for maintenance dredging required for keeping the dredged areas at their minimum water depths and remove any fill-in by sediments.
- **Operation costs (-):** This measure does not require any operational activity.
- **Benefits/income (15):** This measure results in a return on investment after several years of operation.

A2.4.3 Limit dredging activities (focus on smaller ships)

Definition: Limit dredging activities saving maintenance costs and focus port infrastructure on smaller ships (i.e., opposite of accommodating for bigger ships).

Table 21 PPP scores, costs and benefit of limit dredging activities.

Construction	Maintenance	Operation	Total benefit
0	1	-	10

People 1			Planet 1			Prosperity 1		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
2	0	-1	0	0	2	1	1	0

- **People (1):** Smaller ships are expected to operate more frequently at full capacity compared to larger vessels, which results in more job opportunities.
- **Planet (1):** Infrastructure for smaller ships will generally be of a smaller scale and will be less invasive than infrastructure for receiving larger vessels.
- **Prosperity (1):** The port expects to take in more ships without any construction activities, which may benefit the port profit. Lower fees generally associated with smaller ships will have to be compensated by the increase in the number of vessels received.
- **Implementation costs (0):** This measure is more downsizing of activities. Less dredging may be required (particularly at shorter time scales). On the other hand, quays, fenders, bollards and mooring dolphins may have originally been designed and developed for larger vessels and these need to be adapted to accommodate the smaller vessels. We have assumed that these events will cancel out each other.
- **Maintenance costs (1):** The maintenance costs to keep the infrastructure up to standard.
- **Operation costs (-):** This measure does not require any operational activity.
- **Benefits/income (10):** This measure results in a return on investment after several years of operation.

A2.4.4 Upgrade handling equipment

Definition: Introduce new or upgrade existing handling equipment to automate cargo handling activities.

Table 22 PPP scores, costs and benefit of upgrade handling equipment.

Construction	Maintenance	Operation	Total benefit
6	-1	0.5	9

People			Planet			Prosperity		
2			1			2		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
0	0	3	1	2	0	1	0	3

- **People (2):** The upgrading action helps to extend the life of machinery while maximizing the operational safety by introducing state-of-the-art equipment.
- **Planet (1):** The older equipment which is upgraded with the latest technology can also reduce the energy consumption and decrease greenhouse gas emission.
- **Prosperity (2):** The upgrading action also helps increase the efficiency and productivity of machinery, which creates positive impacts on Prosperity.
- **Implementation costs (6):** This measure requests investment on buying supporting materials or services.
- **Maintenance costs (-1):** The upgrading action is essentially saving maintenance costs, compared with the older equipment. Therefore, the maintenance costs are minus.
- **Operation costs (0.5):** This cost is for operating the equipment.
- **Benefits/income (9):** This measure results in a return on investment after several years of operation.

A2.4.5 Expand storage infrastructure

Definition: Increasing storage capacity for cargo in the port.

Table 23 PPP scores, costs and benefit of expand storage infrastructure.

Construction	Maintenance	Operation	Total benefit
4	0.5	-	2

People			Planet			Prosperity		
0			0			2		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
1	-1	0	-2	-1	2	2	1	2

- **People (0):** The expanded measure creates more job opportunities. Other than that, the storage facilities will mainly take up space and possibly lead to visual obstructions. We have assumed that these influences will cancel out each other.
- **Planet (0):** The expansion will occupy more open space within the port. Thus, it causes negative impacts on environmental quality and climate change mitigation. The new infrastructure is expected to expand towards inland, which is less vulnerable to natural hazard.

- **Prosperity (2):** For accommodating increased cargo flows, the increased storage capacity can accelerate the logistic service and increase port profit.
- **Implementation costs (4):** This measure requests investment on constructive actions, but less than other port expansion measures.
- **Maintenance costs (0.5):** The maintenance costs to keep the infrastructure up to standard.
- **Operation costs (-):** This infrastructure does not require any operation action.
- **Benefits/income (2):** This measure results in a return on investment after several years of operation.

A2.5 Category 5: Strategic planning (total 4 measures)

A2.5.1 Develop new port business opportunities

Definition: Diversify port customer portfolio by focusing on new business opportunities (e.g., offshore industry, renewables, containers, digital devices).

Table 24 PPP scores, costs and benefit of develop new port business opportunities.

Construction			Maintenance			Operation		Total benefit
0			0.5			-		2
People 4			Planet 0			Prosperity 3		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
5	1	1	-2	1	1	2	3	2

- **People (4):** New business opportunities will stimulate industrial investment and consolidate port services, which create more job opportunities.
- **Planet (0):** As the new business opportunities aim for green and emerging industries, these developments will aid in reducing the effects of climate change. Furthermore, new businesses will raise the environmental standard to meet present-day environmental aims.
- **Prosperity (3):** The measure does benefit not only the harbour but also the city nearby. Residents living nearby tend to work around/in the port.
- **Implementation costs (0):** This measure does not require any constructive action.
- **Maintenance costs (0.5):** Maintenance cost mainly aims for a business relationship.
- **Operation costs (-):** This infrastructure does not require any operation action.
- **Benefits/income (2):** This measure results in a return on investment after several years of operation.

A2.5.2 Improve coordination with other port

Definition: Synchronize information systems and planning with other neighbouring ports (single window for information) and focus on core activities (specialization).

Table 25 PPP scores, costs and benefit of improve coordination with other port.

Construction	Maintenance	Operation	Total benefit
0	0.5	-	2

People			Planet			Prosperity		
1			0			3		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
1	0	0	0	0	1	1	0	3

- **People (1):** This measure creates a few job opportunities for coordination.
- **Planet (0):** Exchange of information, including weather and navigation, can aid in dealing with the effects of climate change.
- **Prosperity (3):** Having good coordination with other ports means faster reaction and respond to traffic schedule changes. This measure leads to a better allocation of terminal resources and network planning.
- **Implementation costs (0):** This measure does not require any constructive action.
- **Maintenance costs (0.5):** This cost mainly aims for maintaining information exchange.
- **Operation costs (-):** This infrastructure does not require any operation action.
- **Benefits/income (2):** This measure results in a return on investment after several years of operation.

A2.5.3 Improve employees' expertise

Definition: Provide training programs or technological assistance to improve employee skills & productivity.

Table 26 PPP scores, costs and benefit of improve employee's expertise.

Implementation	Maintenance	Operation	Total benefit
0	0.5	-	2

People			Planet			Prosperity		
2			0			2		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
0	0	3	0	0	0	1	0	3

- **People (2):** The measure can shape personal-safety behaviours and interactions.
- **Planet (0):** No direct impact expected, although indirectly better skilled labourers will mean less incidents and lower probability of incidents, leakages, oil spills etc.
- **Prosperity (2):** Employee's expertise has emerged as a critical driver of improving port operational efficiency.
- **Implementation costs (0):** This measure does not require any constructive action.
- **Maintenance costs (0.5):** This cost mainly aims for maintaining training.
- **Operation costs (-):** This infrastructure does not require any operation action.

- **Benefits/income (2):** This measure results in a return on investment after several years of operation.

A2.5.4 Attract investors

Definition: Marketing activities to attract (external) investments in port developments and upgrades.

Table 27 PPP scores, costs and benefit of attract investors.

Construction	Maintenance	Operation	Total benefit
0	1	-	0

People 2			Planet 0			Prosperity 5		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
3	0	0	0	0	0	3	5	3

- **People (2):** Such activities will increase employment opportunities in the port area, leading to a positive effect on people.
- **Planet (0):** No direct impact.
- **Prosperity (5):** The measure does not only create a direct investment for the harbour but also benefits for the city nearby. Residents living nearby tend to work around/in the port.
- **Implementation costs (0):** This measure does not require any constructive action.
- **Maintenance costs (1):** This cost mainly aims for maintaining a business relationship.
- **Operation costs (-):** This infrastructure does not require any operation action.
- **Benefits/income (0):** The strategic measure is not expected to be earned back soon. General earnings are considered for this measure under 'Prosperity'.

A2.6 Category 6: Regulation (total 6 measures)

A2.6.1 Implement environmental management standard (ISO)

Definition: Enforce implement management standards and associated monitoring systems to control and report on the port's environmental performance.

Table 28 PPP scores, costs and benefit of implement environmental management standard (ISO).

Construction	Maintenance	Operation	Total benefit
1	0.5	-	2

People 3			Planet 3			Prosperity 1		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
1	0	3	4	3	2	0	1	1

- **People (3):** The overall improvement in environmental quality will benefit for the safety of residence around the port.
- **Planet (3):** Implementing ISO has many benefits for ports with environmental management systems. Ports find that using the standard help them improve overall ecological impacts such as resource efficiency, pollution and climate resilience.

- **Prosperity (1):** The measure can also increase stakeholder and customer trust and gain a competitive advantage in the market.
- **Implementation costs (1):** this strategic measure does not need constructive material, thus only require low implementation costs.
- **Maintenance costs (0.5):** this cost mainly aims for maintaining a business relationship.
- **Operation costs (-):** This infrastructure does not require any operation action.
- **Benefits/income (2):** This measure results in a return on investment after several years of operation.

A2.6.2 Apply lifecycle asset management

Definition: Manage port assets for their entire life-cycle from building to disposal/decommissioning (e.g., gain efficiency and/or extend their functional lifetime).

Table 29 PPP scores, costs and benefit of apply lifecycle asset management.

Construction			Maintenance			Operation		Total benefit
1			-0.3			-0.2		2
People 3			Planet 3			Prosperity 2		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
2	0	2	2	2	3	1	2	2

- **People (3) & Prosperity (2):** This measure also optimizes the distribution and allocation of resources (money, equipment and people) in the port, which is beneficial port prosperity, infrastructure safety and employment.
- **Planet (3):** Lifecycle asset management ensures existing infrastructures keep on providing adequate service levels, which makes port assets effective and environmentally-friendly. Higher management standard also improves defence for climate change.
- **Implementation costs (1):** this measure may require small construction for associated infrastructure.
- **Maintenance costs (-0.3):** the improved management of asset is saving maintenance costs; thus, the cost is assigned as a minus.
- **Operation costs (-0.2):** The operation cost reduces due to improved management.
- **Benefits/income (2):** This measure results in a return on investment after several years of operation.

A2.6.3 Incentivize green port concessions

Definition: Provide discounts on port concessions for sustainable customers/industries.

Table 30 PPP scores, costs and benefit of incentivize green port concessions.

Construction	Maintenance	Operation	Total benefit
0	0.5	-	0

People 2			Planet 2			Prosperity -1		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
1	0	2	2	4	0	-2	0	0

- **People (2) & Planet (2):** Since the concessions are expected to lead to emission reductions and environmental improvement, which benefits human and natural health. Therefore, the effect on People and Planet will be positive.
- **Prosperity (-1):** The revenue of the port will reduce because some of the incentives given correspond to discounts on port fees or reduction of other forms of income for the port.
- **Implementation costs (0):** This strategic measure does not need constructive action.
- **Maintenance costs (0.5):** This maintenance cost mainly aims to ensure the implementation in the long term.
- **Operation costs (-):** This infrastructure does not require any operation action.
- **Benefits/income (0):** This strategy measure does not create any income for the port.

A2.6.4 Implement Environment Ship Index (ESI) discounts

Definition: Provide discounts to ships that perform well on the Environmental Ship Index by reducing their emissions and pollution.

Table 31 PPP scores, costs and benefit of implement Environment Ship Index (ESI) discounts

Construction	Maintenance	Operation	Total benefit
1	0.5	-	2

People 2			Planet 2			Prosperity 0		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
1	0	2	2	4	0	0	0	0

- **People (2) & Planet (2):** Apart from the distinct environmental advantages, improved air quality leads to a positive score for healthy human safety. Therefore, a positive rating for the people and planet indicators.
- **Prosperity (0):** The improved image of the ports that adopt the environmentally-friendly ESI scheme is expected to lead to additional port income in the future, which offset the cost for discount.
- **Implementation costs (1):** This strategic measure does not need constructive material, thus only require low implementation costs.

- **Maintenance costs (0.5):** This cost mainly aims to ensure the implementation in the long term.
- **Operation costs (-):** This infrastructure does not require any operation action.
- **Benefits/income (2):** This measure results in a return on investment after several years of operation.

A2.6.5Implement Stricter safety rules

Definition: Additional rules to increase the safety of ships, passengers, workers and goods in the port.

Table 32 PPP scores, costs and benefit of implement stricter safety rules.

Construction			Maintenance			Operation		Total benefit
1			0.5			-		2
People 3			Planet 0			Prosperity 1		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
1	0	4	0	0	0	0	0	2

- **People (3) & Prosperity (1):** The safety rules can be established for the construction, equipment and operation of vessels, while they can also be developed for the handling of dangerous substances and emergency procedures [23]. The positive effects on safety and operational efficiency lead to positive scores for people and prosperity.
- **Planet (0):** No impact.
- **Implementation costs (1):** this strategic measure does not need constructive material, thus only require low implementation costs.
- **Maintenance costs (0.5):** this cost mainly aims to ensure the implementation in the long term.
- **Operation costs (-):** This infrastructure does not require any operation action.
- **Benefits/income (2):** This measure results in a return on investment after several years of operation.

A2.6.6 Improve customs procedures

Definition: Improve customs procedures for more efficient circulation, transit, storage, processing and export.

Table 33 PPP scores, costs and benefit of improve customs procedures.

Construction			Maintenance			Operation		Total benefit
0			0.5			-		0
People 1			Planet 0			Prosperity 4		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
1	0	0	0	0	0	2	0	4

- **People (1):** For improving customs procedures, a few more employees are needed.
- **Planet (0):** No impact.

- **Prosperity (4):** Customs plays a significant role in the logistic chain. The improvement of customs procedures will enhance trade and transport, which increases the income and operational efficiency of the port.
- **Implementation costs (0):** this strategic measure does not any implementation cost.
- **Maintenance costs (0.5):** this cost mainly aims to ensure the measure last in the long term.
- **Operation costs (-):** this infrastructure does not require any operation action.
- **Benefits/income (0):** this strategy measure does not create any income for the port.

A2.7 Category 7: Technology (total 3 measures)

A2.7.1 Improve IT technology

Definition: Implement new IT technology for more effective and efficient port services of high quality (e.g., 5G technology and cargo tracking).

Table 34 PPP scores, costs and benefit of improve IT technology.

Construction			Maintenance			Operation		Total benefit
1			0.5			-		5
People 3			Planet 0			Prosperity 3		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
2	0	3	1	0	0	2	1	3

- **People (3) & Prosperity (3):** IT technology can be used either for better control and management of the port and port infrastructure or the efficiency of logistics processes. Therefore, the measure leads to positive scores on People (especially on safety) and Prosperity.
- **Planet (0):** Improved port operational efficiency and traffic condition will reduce air pollution.
- **Implementation costs (1):** This measure may require a small amount of investment in upgrading supporting equipment.
- **Maintenance costs (0.5):** This cost mainly aims for maintaining supporting equipment work in the long term.
- **Operation costs (-):** This infrastructure does not require any operation action.
- **Benefits/income (5):** This measure results in a return on investment after several years of operation.

A2.7.2 Install innovative mooring techniques

Definition: Implement innovative mooring systems to (keep moored ships stable and reduce forces in mooring lines too) allow for safe operations under more energetic wave conditions.

Table 35 PPP scores, costs and benefit of install innovative mooring techniques.

Construction	Maintenance	Operation	Total benefit
2	0.5	-	4

People			Planet			Prosperity		
1			1			1		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
0	0	1	0	0	2	1	0	2

- **People (1), Planet (1) & Prosperity (1):** The innovative mooring techniques allows vessels to be kept in place adequately, making efficient loading and unloading possible even under more challenging wave conditions. Thus, the methods lead to positive impacts on climate change vulnerability, safety and operational efficiency.
- **Implementation costs (2):** This measure needs investment in supporting equipment.
- **Maintenance costs (0.5):** This cost mainly aims for maintaining supporting equipment work in the long term.
- **Operation costs (-):** This infrastructure does not require any operation action.
- **Benefits/income (4):** This measure results in a return on investment after several years of operation.

A2.7.3 Implement weather & pollution monitoring system

Definition: Develop a weather and pollution monitoring system providing early warnings on waves, water levels, currents conditions and ecology parameters.

Table 36 PPP scores, costs and benefit of implement weather & pollution monitoring system.

Construction	Maintenance	Operation	Total benefit
2	0.5	-	2

People			Planet			Prosperity		
3			2			1		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
2	0	3	2	1	3	0	2	0

- **People (3), Planet (2) & Prosperity (1):** The weather monitoring system will enhance the climate resilience of the port and therefore, the safety against climate change. The pollution monitoring activities will benefit the overall environment inside the port and around the port city area.
- **Implementation costs (2):** this measure needs investment in supporting equipment.
- **Maintenance costs (0.5):** this cost mainly aims for maintaining supporting equipment work in the long term
- **Operation costs (-):** This infrastructure does not require any operation action.
- **Benefits/income (2):** This measure is regard as a consumable to the port, rather than a source of revenue. Thus, the implementation costs of a weather and pollution monitoring system are not expected to be earned back soon.

A2.8 Category 8: Public service (total 4 measures)

A2.8.1 Increase public green space for leisure & recreation

Definition: Increase the public green space for leisure and recreational activities with facilities such as restaurants, accommodation, sports and museums.

Table 37 PPP scores, costs and benefit of increase public green space for leisure & recreation.

Construction	Maintenance	Operation	Total benefit
5	0.5	-	10

People			Planet			Prosperity		
5			3			1		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
2	5	1	4	2	1	0	2	0

- **People (5), Planet (3) & Prosperity (1):** This measure means that the residents will experience improved well-being, while the public green space can offer various environmental advantages. The action will attract more tourism for the city and therefore will contribute to increasing job opportunities and city revenue.
- **Implementation costs (5):** This measure needs investment in constructing infrastructure.
- **Maintenance costs (0.5):** This cost mainly aims for maintaining the infrastructure work in the long term.
- **Operation costs (-):** This infrastructure does not require any operation action.
- **Benefits/income (10):** This measure results in a return on investment after several years of operation.

A2.8.2 Contribute to public education

Definition: Provide lectures and educational programs in local schools.

Table 38 PPP scores, costs and benefit of contribute to public education.

Construction	Maintenance	Operation	Total benefit
0	0.25	-	1

People			Planet			Prosperity		
2			1			1		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
1	0	2	1	1	1	0	2	0

- **People (2), Planet (1) & Prosperity (1):** The increased focus on public education will raise awareness of the environment and safety. Besides, public service is expected to enhance port-city cooperation.
- **Implementation costs (0):** This planning measure does not include any implementation cost.
- **Maintenance costs (0.25):** This cost mainly aims for maintaining the activities in the long term.
- **Operation costs (-):** This infrastructure does not require any operation action.

- **Benefits/income (1):** This measure results in a return on investment of operation in very short term.

A2.8.3 Invest in port-related research & innovation

Definition: Invest in research and development activities together with knowledge partners to increase port productivity.

Table 39 PPP scores, costs and benefit of invest in port-related research & innovation.

Construction	Maintenance	Operation	Total benefit
0	0.5	-	0

People			Planet			Prosperity		
1			1			1		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
1	0	1	1	1	1	0	1	1

- **People (1), Planet (1) & Prosperity (1):** Apart from the similar impacts as the measure of public education, the port operational efficiency will be improved by innovative actions.
- **Implementation costs (0):** This planning measure does not require any implementation cost.
- **Maintenance costs (0.5):** This cost mainly aims for maintaining the activities in the long term.
- **Operation costs (-):** This infrastructure does not require any operation action.
- **Benefits/income (0):** The activities will bring direct revenue to the port.

A2.8.4 Invest in real estate waterfront development

Definition: Develop part of the waterfront of the port with real estate for housing and companies.

Table 40 PPP scores, costs and benefit of invest in real estate waterfront development.

Construction	Maintenance	Operation	Total benefit
15	1	-	32

People			Planet			Prosperity		
4			-1			1		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
1	4	2	0	0	-2	0	2	0

- **People (4), Planet (-1) & Prosperity (1):** The measure is expected to generate more recreation and job opportunities in the port-city area and increase the connection between port and city. However, the waterfront real estate increases the risk of climate-related events. Although this measure will lead to limited profits for the port, it may be a measure to improve the port-city relations and the relations with the people in the area.
- **Implementation costs (15):** This measure needs a large investment in changing the functions of older port areas to residential areas. In practice costs will be shared with the

municipality and project developers. Furthermore, buyers of real estate will bring in income to the project developers ('Prosperity').

- **Maintenance costs (1):** This cost mainly aims for maintaining infrastructure.
- **Operation costs (-):** This infrastructure does not require any operation action.
- **Benefits/income (32):** This measure is likely to result in a return on investment of several years operation.

A2.9 Category 9: Environment (total 6 measures)

A2.9.1 Implement carbon capture storage

Definition: Use carbon capture storage technology to capture CO_2 emissions produced by port related activities.

Table 41 PPP scores, costs and benefit of implement carbon capture storage.

Construction			Maintenance			Operation		Total benefit
2			0.5			-		2
People 1			Planet 2			Prosperity 0		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
1	0	0	1	3	0	1	0	0

- **People (1):** Constructive and maintenance requires a few more labourers.
- **Planet (2):** The technology prevents the CO_2 efficiently from entering the atmosphere, therefore leads to a positive impact on climate change migration and environmental quality.
- **Prosperity (0):** The implementation of the measure is expected to improve the environmentally-friendly image of the port, which will bring additional revenue in the future.
- **Implementation costs (2):** This measure may need investment in supporting equipment.
- **Maintenance costs (0.5):** This cost mainly aims for maintaining equipment.
- **Operation costs (-):** This infrastructure does not require any operation action.
- **Benefits/income (2):** This measure results in a return on investment of operation in very short term.

A2.9.2 Improve waste recycling

Definition: Facilitate collection, separation and reuse of waste materials in the port.

Table 42 PPP scores, costs and benefit of improve waste recycling.

Construction			Maintenance			Operation		Total benefit
1			1			-		2
People 4			Planet 2			Prosperity 1		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
1	0	3	3	1	0	0	1	1

- **People (4), Planet (2) & Prosperity (1):** Aside from the positive effects on environmental quality and safety, this measure will enable levels of employment to be slightly increased and operational activities to be maintained, meaning positive scores of prosperity and people.
- **Implementation costs (1):** This measure may need investment in supporting equipment.
- **Maintenance costs (1):** This cost mainly aims for maintaining equipment.
- **Operation costs (-):** This infrastructure does not require any operation action.
- **Benefits/income (2):** This measure results in a return on investment of operation in very short term.

A2.9.3 Integrate sanitation & wastewater treatment

Definition: Centralize wastewater facilities in the port (instead of scattered facilities) to optimize the system, save space and create opportunities for energy production from sludge.

Table 43 PPP scores, costs and benefit of integrate sanitation & wastewater treatment.

Construction			Maintenance			Operation		Total benefit
20			2			1		35
People 4			Planet 3			Prosperity 2		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
1	1	4	4	2	1	1	2	1

- **People (4), Planet (3) & Prosperity (2):** This measure causes a significant positive effect on water quality, which can, in turn, benefit the quality of human life and safety. The integrated sanitation is expected to save the cost of maintenance and space for other port activities. Therefore, it will lead to a positive impact on port profit.
- **Implementation costs (20):** This measure may need investment in infrastructure.
- **Maintenance costs (2):** This cost mainly aims for maintaining infrastructure.
- **Operation costs (1):** This infrastructure requires simple operation action.
- **Benefits/income (35):** This measure is likely to result in a return on investment of several years operation.

A2.9.4 Natural habitat restoration & rehabilitation

Definition: Restore/rehabilitate and protect natural ecosystems in and around the port to offset the environmental impacts of the port development.

Table 44 PPP scores, costs and benefit of natural habitat restoration & rehabilitation.

Construction			Maintenance			Operation		Total benefit
4			0.1			-		4
People 5			Planet 5			Prosperity 1		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
2	3	3	5	3	5	0	2	0

- **People (5):** Constructive and maintenance require a few more labours. Increased natural area create more space for recreation and improve defence for extreme weather.
- **Planet (5):** The measure has a significant benefit on the ecosystems, leading to an overall very positive score for Planet.
- **Prosperity (1):** The new habitats will attract more tourism, boosting the port-city development.
- **Implementation costs (4):** This measure may need investment in construction work.
- **Maintenance costs (0.1):** This cost mainly aims for protection.
- **Operation costs (-):** This infrastructure does not require any operation action.
- **Benefits/income (4):** This measure results in a return on investment of operation in very short term.

A2.9.5 Coastal protection by revetments

Definition: Protect the coastline from (port-induced) coastal erosion by hard structures.

Table 45 PPP scores, costs and benefit of coastal protection by revetments.

Construction	Maintenance	Operation	Total benefit
10	1	1	11

People 1			Planet 0			Prosperity 0		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
0	0	1	-2	0	3	1	0	0

- **People (1):** Revetments slightly increase the safety of harbour due to the improved defence for extreme weather.
- **Planet (0):** Coastal protection ensures the port city is not vulnerable to extreme weather phenomena. However, artificial infrastructure disturbs the original ecosystem.
- **Prosperity (0):** Improved safety, in turn, benefits to port profit by saving costs.
- **Implementation costs (10):** This measure needs investment in construction work.
- **Maintenance costs (1):** This cost mainly aims for maintaining the artificial infrastructure.
- **Operation costs (1):** This infrastructure requires low operation costs.
- **Benefits/income (11):** This measure results in a return on investment of operation in short term.

A2.9.6 Coastal protection through Building with Nature

Definition: Protect the coastline from (port-induced) coastal erosion by soft or hybrid measures using the forces of nature (e.g., mangrove greenbelts, vegetated saltmarshes, nourishments).

Table 46 PPP scores, costs and benefit of coastal protection through building with nature.

Construction	Maintenance	Operation	Total benefit
5	2	1	11

People			Planet			Prosperity		
3			3			1		
Employment	Recreation	Safety	Environmental quality	Climate change mitigation	Climate change vulnerability	Port profit	Port-city development	Port operational efficiency
1	2	2	3	2	4	0	2	0

- **People (3) & Prosperity (1):** The hydraulic engineering solution provides added value for nature and social functions, leading to the improvement of the quality of the coastline and may subsequently increase tourism and employment.
- **Planet (3):** The measure can function as stabilising or protecting agents because they reduce wave and current energy levels, meaning positive impacts on decreasing climate change vulnerability. Increased natural areas will improve general environmental quality and mitigate port activities impacts on climate change.
- **Implementation costs (5):** This measure needs investment in construction work. Economy of scale may help reduce costs if a larger measure is implemented at once and forces of nature are used for further distribution of materials.
- **Maintenance costs (2):** This measure cost slightly higher than the artificial infrastructure, due to the vulnerability of its natural feature.
- **Operation costs (1):** This infrastructure requires low operation costs.
- **Benefits/income (11):** This measure results in a return on investment of operation in short term.

Annex 3: Scenarios, storylines and effects on PPP scores

This appendix provides an overview of the different scenarios, their storylines and the initial PPP scores (included below in the coloured tables per scenario) that will be present at the start of the serious game session.

A3.1 Scenario 1: Climate change adaptation

Storyline: The climate change adaptation scenario describes a future world of very rapid economic growth which opens up good business possibilities for the port. Meanwhile, the increasingly severe changes in climate threaten the safety and the prosperity of the port. How does the port tackle climate change?

People	Planet	Prosperity
-3	-5	0

This scenario serves to inform players on how to deal with climate change impacts more comprehensively. In this scenario, climate change increases the vulnerability of the port and threats the safety of people and ship navigation. The scores on People and Planet are assigned minus to trigger players to fight the impacts of climate change and to make the port less sensitive to these impacts. The scenario is suitable for ports that:

1) have not taken any climate adaptation action yet;
2) want to consider different climate change scenarios
3) want to explore how to respond to climate change.

A3.2 Scenario 2: Energy transition

Storyline: The energy transition scenario emphasis on increases in green energy, energy efficiency and green modal split in the port.

People	Planet	Prosperity
0	-4	-3

This scenario aims to let players understand the potential positive and negative consequences of energy transition measures. The scenario starts with the setting that a port is facing the challenges of combating greenhouse gas emission because of present use of fossil fuels. Therefore, the initial score for Planet is set as -4. The poor air quality also affects the port operational efficiency and profit. The scores on Planet and Prosperity are low to stimulate players to take actions of the energy transition. The scenario is suitable for ports that:

1) want to explore how to facilitate the energy transition and deal with the associated challenges;
2) are interested in testing different energy-ransition related measures, such as ‘optimization power grid for renewable energy’ and ‘provide on-shore power to ships’;
3) are interested in energy transition scenarios.

A3.3 Scenario 3: Economic stagnation

Storyline: This scenario describes a world with a stagnating economy. The port and city are seeking new business opportunities.

People	Planet	Prosperity
-2	0	-5

The goal of this scenario is helping port explore how to prepare for economic stagnation. The impacts of global economic decline, such as less cargo throughput and unemployment in the port-city region, affect the port. Therefore, the scores of prosperity and people of the port are set as a minus. The scenario is suitable for ports that:

1) function as one of the most significant economic pillars for the city /region;
2) would like to explore the possibilities to respond to economic stagnation

A3.4 Scenario 4: Innovation

Storyline: The scenario describes a world in which the emphasis is on innovation and technological solutions. The society believes that innovation will bring new business opportunities and improve port operational efficiency and safety.

People	Planet	Prosperity
0	-1	-3

Via this scenario, players learn the benefits and risks of investment on innovation, e.g. people are not ready for it, resulting unemployment in traditional business sectors. At the beginning of the scenario, the scores of the planet and prosperity are low. The port needs to take actions on innovation, which can help the port improve its operational efficiency, the safety of labour and city traffic condition. The scenario is suitable for ports that:

1) plan to implement or consider introducing more innovative technologies in the port;
2) do not know how to deal with innovation and its potential positive/negative impacts;
3) want to explore how to deal with potential benefits and risks of technological innovation.

A3.5 Scenario 5: Sustainable city-port development

Storyline: The scenario describes a world in which the emphasis is on city and port cooperation on the topics of social sustainability.

People	Planet	Prosperity
-2	-3	0

The goals of the scenario are educating players about the importance of social and environmental impacts on port development and helping them seek city-port cooperation for increasing port profit. The scenario is set as the port-city region suffering from noise, traffic

pressure and pollution caused by the port activities. Therefore, the scores on People and Planet start off low to trigger discussion among the players. The scenario is suitable for ports that:

1) face environmental and social challenges;
2) did not plan environmental protection or social measures, would like to see the benefits of them;
3) have no social service and willing to see the potential impacts of such services on the port;
4) want to operate sustainably/in harmony with society and environment

A3.6 Scenario 6: Neutral scenario

Storyline: The neutral scenario is for simulating future planning and guiding toward sustainable development under average conditions.

People	Planet	Prosperity
0	0	0

The scenario aims to guide players in sustainable development of the port. Scores on PPP set as null which give the facilitator more freedom to set a proper scene for the workshop. The scenario is suitable for ports/users that:

1) are not directly port-related personnel but interested in sustainable development, such as students;
2) want to inform contacts that have no experience/background on port development, e.g. students;
3) have multi goals they equally would like to consider and explore.

Annex 4: Events, associated special news and effects on PPP scores

This appendix describes events, associated special news and their direct effects on PPP scores (represented below in the coloured tables included in the description of each event).

A4.1 Event category 1: Unemployment

Two reasons can cause peaks in unemployment. One is due to the overall economic downturn; the other is the threats from emerging industries to traditional industries. Therefore, the unemployment events result in declined scores on People and Prosperity.

This event category contains two news as described below:

1) Big strike: workers fear to lose their jobs: The rapid changes in the economy and technology make the workers in traditional industries feel insecure. Workers are afraid to lose their jobs and demand action!

People	Planet	Prosperity
-3	0	-1

2) Unemployment rate at highest since 1990: The unemployment rate is sky-high. There are big demonstrations in the city and politicians put increasing pressure on the port to take action.

People	Planet	Prosperity
-3	0	-1

A4.2 Event category 2: Climate change

Climate change brings about two far-reaching consequences. Within the context of this scenario, in the short-/mid-term, climate change causes extreme weather, such as storming, flood, and high waves. In the long-term, it is projected to cause also a rise in sea level. The consequences not only change the natural environment but also threaten the safety of human and port operation. According to the extent of the effect, the scores on PPP are assigned slightly different.

This event category contains two news as described below:

1) Hurricane Corealis hits the port: A massive hurricane has hit the port and has shut down port activities for days. Companies ask for better protection; else they will relocate their activities.

People	Planet	Prosperity
-2	-2	-3

2) The port is about to lose the battle against rising sea levels: Protection against sea level rise and flooding found to be inadequate. Safety of people and companies is at stake; they demand the port to take measures.

People	Planet	Prosperity
-3	0	-3

A4.3 Event category 3: Infrastructure

The aims of infrastructure events are reminding the participants of risks that may be overlooked when players focus on investing emerging measures. If the infrastructure lags behind the planning, it will require extra measures to secure port operations. Therefore, the effects on Prosperity is assigned as a minus.

This event category contains two special news as described below:

1) Port infrastructure not ready: The port's infrastructure is not yet ready for the transition. Infrastructure upgrades are required to continue port operations and secure its profitability.

People	Planet	Prosperity
0	0	-3

2) Chaos due to IT network breakdown: Due to a long network interruption activity in the port have shut down entirely. What is the port's fallback option?

People	Planet	Prosperity
0	0	-3

A4.4 Event category 4: Pollution

Port activities can cause a variety of pollution, including air pollution, water pollution, soil pollution and noise. No matter which type of pollution, it affects human health and the ecosystem. Therefore, only air pollution is taken as a representative example of an unexpected event.

1. The pollution event is about smog forcing people to stay inside: Air pollution from port starts to cause trouble! The living and working conditions are below-standard due to deterioration of air quality.

People	Planet	Prosperity
-3	-3	0

A4.5 Event category 5: Economy

Economic events aim to persuade players to shift their focus on increasing prosperity. Therefore, by reducing scores on People (unemployed) and Prosperity (profit decrease), the events trigger players to discuss measures on saving its market share.

This event category contains two special news as described below:

1) Recession: It is time for the port, and the city to work together in finding additional investors and save and create jobs.

People	Planet	Prosperity
-3	0	-3

2) Companies in the port are not satisfied with the port policy: Terminal operators complain about the port's focus on social and environmental matters. Something needs to change, as they start to relocate their activities.

People	Planet	Prosperity
-2	0	-3

Annex 5: Instructions for the digital simulation environment

This section provides a quick guide on how to use the digital simulation environment of the game. In the following sections, the instructions are described step-by-step (based on screenshots):

1. Starting the program and start menu
2. Scenario selection
3. The main screen and menu
4. Measure selection and visualization
5. Event selection and visualization
6. End screen

A5.1 Starting the program

The first step to run the program is to double click on the game icon named "Port of the Future.exe". After the game has started, the introductory dialogue box appears (Figure 11). Here, the player can choose the resolution (related also to projector specifications used), the quality of the graphics and the monitor on which the game will be displayed (if applicable). Unchecking "Windowed" will run the program in a full screen mode; otherwise, it will run in a window. The "Input" tab describes all the keys that can be used in the game and their function. By clicking on "Play!" the game starts.

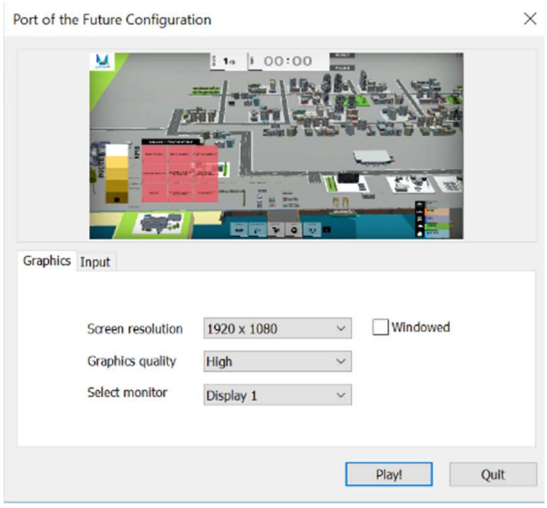

Figure 11 The configuration screen after starting the PoFSG software

When the game starts, the start menu displays (Figure 12). In this menu, the player can directly move on to the gameplay by clicking "Play scenario". Alternatively, the player can select the preferred language prior to the gameplay by clicking "Language". In the present version only English (default) is implemented. In the future we foresee the implementation of Spanish and French. The player is also able to find information on the game development by clicking "About".

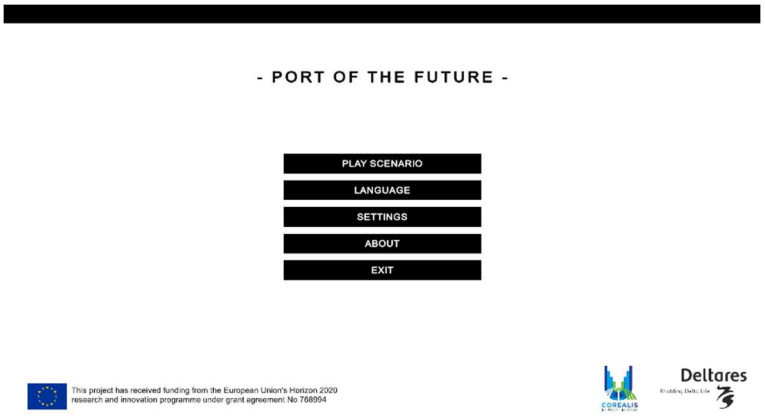

Figure 12 The start menu

A5.2 Scenario selection

Upon starting a game session, a scenario needs to be selected from a list of six implemented scenarios (Figure 13). After selecting one of the scenarios, click "play" to reach the next step.

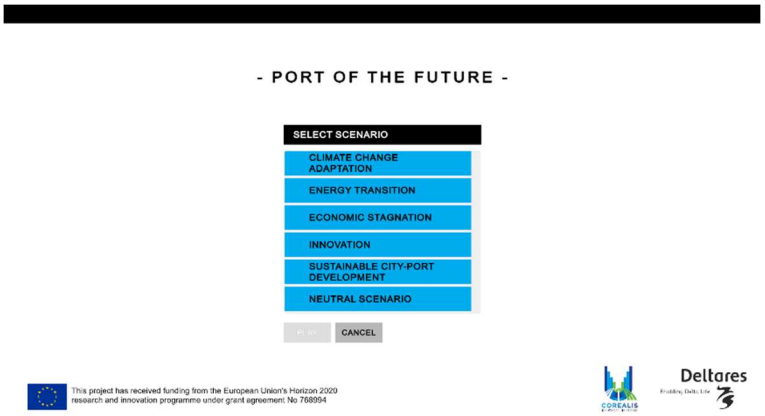

Figure 13 Scenario selection menu

A5.3 The main screen and menu

The main screen presents a graphical illustration of the port-city (Figure 14). On the top, there are boxes indicating the round number of the game session and a timer which shows the available time left in the present round. The available game time can be changed by the facilitator by clicking on the time numbers and entering the time that is given to the players for the next round. Below the timer, the initial values of People, Planet, Prosperity and budget are presented.

Figure 14 Main screen

On the top-left corner is the icon will unfold the main menu (Figure 15). In the main menu, the facilitator can select measures and events in order to proceed to the next step in the game. By clicking the button "Select measures" the player will reach the measure list. The button "Select events" can lead the player to the list of events. After a few rounds, the player can end the gameplay by clicking "End game", which will result in an overview (i.e., summary) of the game session.

The player can go back to the start menu by clicking "Back to start menu" on the right part of the main menu. It is also possible to drop out of the game by clicking "Exit the game". There is a button "COREALIS SITE" connecting to the official website of COREALIS.

Figure 15 Main menu

A5.4 Measure selection and visualization

There are two ways of selecting measures in the measure selection box, which is presented in Figure 16 (left): 1) click the "Scan" button and scan the QR code via the camera of the computer and 2) click the "List" and scroll up or down to find the selected measures. Click the measures and press "add measure" to implement the selected measure (i.e., which moves the measure to the far-right column). Once all the selected measures display on the far-right column, click "Next round" for implementing the measures and proceed to the next round. A dialog box appears to confirm the selection, as shown in Figure 16 (right).

Figure 16 Measure selection box (right), the dialog box of confirming the selection (right).

Once the selection of measures is confirmed, the main screen will zoom in to the respective locations where the measures are implemented. The animated demo of the measures will be displayed, with the associated changes in PPP values at the bottom of the screen (Figure 17).

Figure 17 Example of animated demonstration of measure 'integrate sanitation & wastewater treatment'.

Following with the animation of measures (or events), the main screen shows the effects of the selection on PPP and budget in the scoring boxes at the top (Figure 18). The changes in values (i.e., positive, neutral or negative) after implementing measures or events will be highlighted with sparkling arrows.

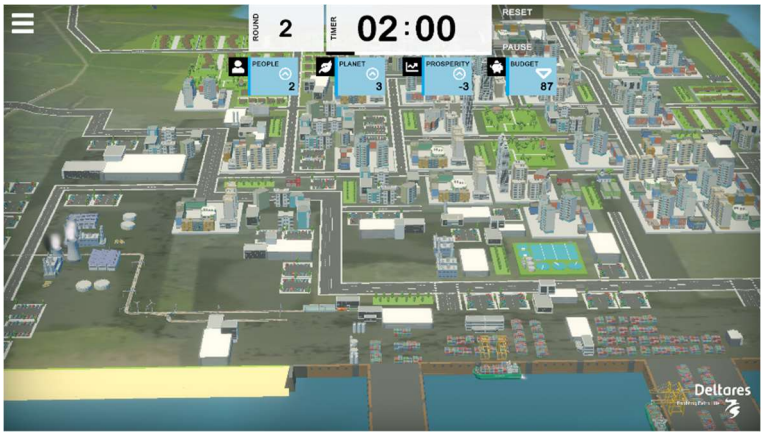

Figure 18 Effect on PPP value and budget is displayed

A5.5 Event selection and visualization

If the player decides to select an event, an event selection box will display, as shown in Figure 19 (left). Similar to the selection of measures, the player can select an event either via scanning the QR code behind the newspaper or click the name of the event and confirm by clicking the "Continue" button. Then the special news item will be displayed, as presented in Figure 19 (right). The player can click "Continue" to display/implement the event.

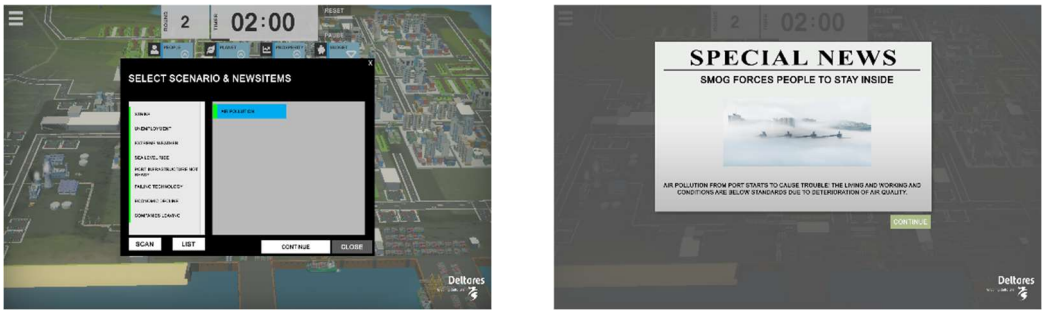

Figure 19 Event selection box (right), the dialog box of confirming the selection(right).

Once the selection of event is confirmed, the corresponding event will be displayed on the main screen with the associated effects on the PPP values at the bottom (Figure 20).

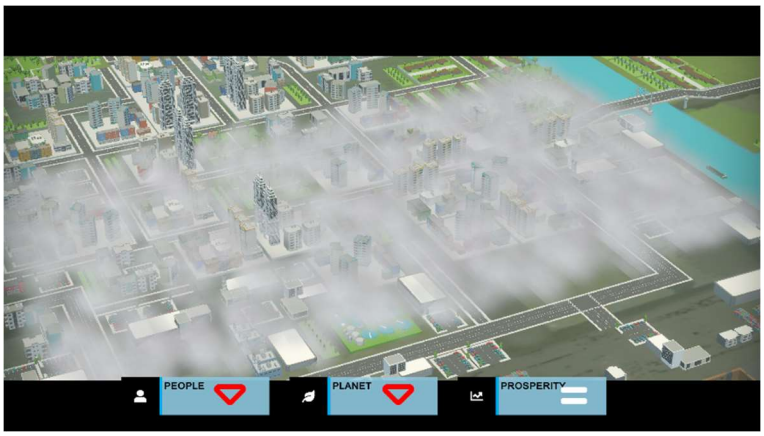

Figure 20 Example of animated demonstration of the event "air pollution"

A5.6 End screen

If the player selects "End game" in the main menu, an end screen will display (Figure 21). The end screen shows a screenshot of the initial port (left) and the port after implementing the different measures as selected during the gameplay (right). The values of PPP and budget at the beginning and end of the game are displayed at the top of the screen. An overview of the selected measures and events included in the game session are listed at the bottom of the screen.

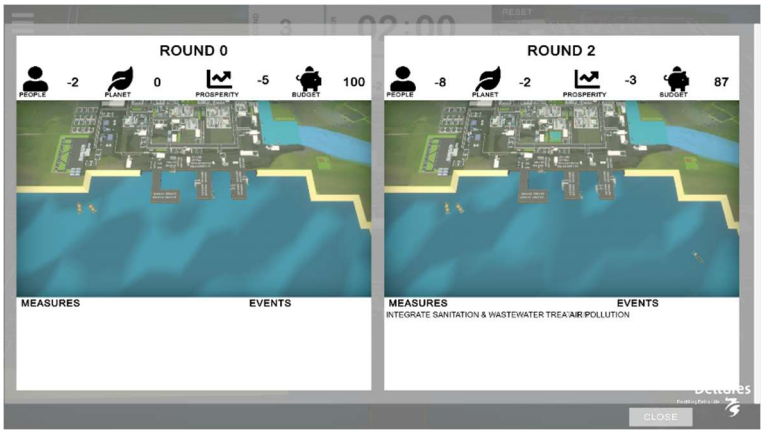

Figure 21 Closing screen, showing both the initial scores (left) and the outcome of the game session (right).