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D4.1 – PIXEL Models

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Type	Other	Dissemination Level	Public
Version	1.0	Status	Final
Description	This deliverable is focused on PIXEL Models. It includes a description of the overall methodology for the environmental management of port and a description of the models, algorithms and numerical methods for each model. This is the first version of the deliverable.		
Work Package	WP4		

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History

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18-DEC-2018	0.2	Add contributions from partners
27-DEC-2018	0.3	Intermediate version shared with all WP4 partners
28-JAN-2019	0.5	Review and comments by PIC
31-JAN-2019	1.0	Official release

Key Data

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Abstract

Port activities undeniably have an impact on their environment, on the city and the citizens living nearby. To have a better understanding of these impacts, ports needs tools allowing suitable modelling, simulation and data analysis. The ports (PIXEL' s partner) highlight in this document their needs to have a better understanding of these impacts by using modelling, simulation and data analysis. The topics of interest of the ports are currently:

- Modelling the consumption and energy production of the port with the aim of moving towards green energy production (Port of Bordeaux).
- Congestion modelling of multimodal transport networks in order to reduce the impact of port traffic on the network and thus minimize associated environmental impacts (Ports of Monfalcone and Thessaloniki).
- Modelling the environmental pollution of the port (dust, air pollutants, noise) with the aim of reducing the environmental impacts of the port on the city and its citizens (Ports of Piraeus and Thessaloniki).

The present report aims to summarize the result from first steps of Work Package 4: an analysis of possible directions for PIXEL's models.

In order to developed PIXEL models fitting the different needs expressed by ports, this document first focus on the description of port activities to model and the available data in ports. The topics of interest of the ports are identified with a precision allowing to build the models' specifications. This is one of the essential information provided by the present document. This document also describes how PIXEL models are linked with Port Environmental Index (that is developed in parallel) and how these models will be integrate in the overall PIXEL Hub and Architecture. This corresponds to a shared work with other PIXEL’s work package on definition of use case needs, available data, expected outputs and their integration in the overall PIXEL architecture.

This document also highlights common elements to all models. This definition work provides the main underlying logic, the common vocabulary and the definition of key concepts. Although some sophistications may be added later, these points should form the common basis for the design of PIXEL models. To meet the needs put forward by the ports, we first rely on the modelling of the supply chain associated with the different cargoes. Based on activity data, operational data and machines specifications, emission factors and boat planning we aims at being able to identify sources of consumption, emissions and the way cargoes go out from the port. Then, the models and / or data analysis that are envisaged to be used and integrated in the PIXEL architecture are presented. A clear inventory of constraints and risks that must be managed in order to obtain a valuable set of models is provided.

The second part of the document is a description of the different PIXEL’s models. For each of them, the addressed ports' issue is developed. From the interpretation of user stories, a more general list of requirements and features is built up. Special attention is given to the fact that the design of the solution is based on the concrete needs of the users and the practical constraints. In a second step we establish a synthesis of the state of the art (from the academic point of view and market solutions). From this knowledge, as well as lists of objectives and constraints defined above, one or more possible approaches is selected. These ones will be studied more deeply before development and validation. The operational implementation and the real integration in PIXEL will be done in a second time.

Statement of originality

Table of contents

List of tables

List of figures

List of acronyms

Acronym	Explanation
AIS	Automatic Identification System
API	Application Programming Interface
ASPM	Azienda Speziale Porto di Monfalcone
BTEX	Benzene, toluene, and the three xylene isomers
CCS	Cargo Community System
CMSAF	Climate Monitoring Satellite Application Facility
EMP	Environmental Management Plan
EPMS	Electrical Power Management Systems
ESPO	European Sea Ports Organisation
FAL	Facilitation of International Maritime Traffic
GCS	Gate Control System
GHG	Green House Gases
GloMEEP	Global Maritime Energy Efficiency Partnerships
GPMB	Grand Port Maritime de Bordeaux - Port of Bordeaux
IAPH	International Association of Ports and Harbors
IMO	International Maritime Organization
INSIEL	INformatica per Il SEstem degli Enti Locali
ISO	International Organization for Standardization
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
LSFO	Low Sulphur Fuel Oil
MDO	Marine Diesel Oil
NoMEPorts	Noise Management in European Ports
NREL	National Renewable Energy Laboratory
NSRD	National Solar Radiation Database
NTUA	National Technical University of Athens
PCS	Port Community System
PEI	Port Environmental Index
PERS	Port Environmental Review System
PIXEL	Port IoT for Environmental Leverage
PM_{10}	Particulate Matter 10um
$PM_{2.5}$	Particulate Matter 2.5um
PMIS	Port Management Information System
PPAgIS	Piraeus Port Authority SA
PVSIG	PHotovoltaic Geographical Information System
Ro-Ro	Roll On-Roll Off
SAM	System Advisor Model
SCADA	Supervisory Control and Data Acquisition
SDAG	Stazioni Doganali Autoportuali Gorizia
SDK	Software Development Kit
SDM	Self-Diagnosis Method

SILI	Sistema Informativo Logistico Integrato (Integrated Logistic Informated System), a system provided by Regione Friuli Venezia Giulia and managed by Insiel tomonitor and authorize entries to the Ports of Monfalcone and Trieste; it also monitors dangerous goods flows along the regional motorway network
SQL	Structured Query Language
TEU	Twenty-foot equivalent unit
THPA	Thessaloniki Port Authority
TMS	Traffic Management Centre
UI	User Interface
WP	Work Package

1. About this document

This document aims to present the models and data analysis that will be implemented as part of the PIXEL project. These ones deal with issues of energy consumption and production, multimodal transport and environmental pollution in order to improve the environmental management of ports. These models and data analysis are essentially based on the needs expressed by the 4 ports of the project. However, PIXEL also has a generalist scope and will try to develop useful models that can be employed by other ports.

In this document, we present the first considerations on models and data analysis that will be developed later, and we define the first technical bases for their implementation. This document and its next iteration (D4.2) will provide a complete description of PIXEL models: by reading D4.1 and D4.2 readers will have a description of the overall methodology for the environmental management of port and a description of the models, algorithms and numerical methods for each model.

This document also provides the basis for the development of PIXEL Operational Tools (WP6) as well as for the real test and implementation phase of PIXEL within ports (WP7).

1.1. Deliverable context

Table 1: Deliverable context

Keywords	Lead Editor
Objectives	*Objective 4: Model and simulate port-operation processes for automated operation* This deliverable provides first specifications of the PIXEL models and data analysis. The methodology to achieve the modelling of port-operation processes is described and some first insights are described. *Objective 5: Develop predictive algorithms* By describing modelling needs of ports, this deliverable contributes to identify possible candidates for predictive algorithms that have the potential of significantly increase the efficiency of ports.
Exploitable results	This deliverable contributes to develop interoperability of environmental related models by identifying the inputs and outputs of each model and describing a methodology considering impacts of energy and transport on environmental pollution. This deliverable also contributes to a better identification of predictive algorithms that could be used to improve port efficiency by mitigating environmental impacts.
Work plan	This deliverable integrates the first work done in WP4 (T4.1, T4.2, T4.3, T4.4 and T4.5). This document also has a close link with WP3: use-cases description (T3.3) and requirements specification (T3.4); with WP5: methodology (T5.1) and KPI definition (T5.2); with WP6: models will be integrated in PIXEL Operational Tools (T6.4) and with WP7 as models will be tested in real conditions.
Milestones	This deliverable contributes to reach the milestone MS4 by providing a first version of the PIXEL Models.

Deliverables	This deliverable uses inputs from the deliverable D3.3 and D3.4 in order to identify modelling needs of ports. This deliverable has a close interaction with the deliverable D3.2 regarding the definition of a set of minimum requirements regarding modelling and data analysis. It also gives inputs for D4.3 and D4.4 by contributing to identify possible candidates for predictive algorithms. It will impact other project activities relating with models and data analysis (integration WP6 and real test WP7).
Risks	By working with the WP3 (T3.3) and with an analysis of every port-operation process to be modelled this deliverable reduces the risk that some processes cannot be modelled as they depend on too many factors or they are overmuch random. The deliverable includes a technical description of the different use-cases regarding modelling and data analysis and provides information about available data and modelling scope.

1.2. The rationale behind the structure

As a first step, this document introduces the global vision of PIXEL models by presenting the roadmap that has been shared with all WP4 partners. In this section, we present the vision, the objectives and the scope of the models in the framework of PIXEL. This first part of this document also aims to make the link with the other WPs of the project and to put the work of modelling and data analysis in the overall context of the project. We also define notions common to all models and take the time to describe the risks, limitations and hypotheses associated with the development and use of models in PIXEL.

The second part of the document is devoted to the description of each model. For each topic, we present a state-of-the-art and existing works and tools. This allows us to identify existing solutions that can be integrated into PIXEL. Our goal is not to develop models if there are already solutions to the problems and needs of ports. The main added value of PIXEL in terms of modelling and data analysis lies mainly in the interoperability of models. As an initial guess we can envision the models to be developed modular to better fine-tune each port. Thus, models could be composed of core model and plugins to better suit the needs of a port. Subsequently, we describe for each of the models the necessary data and the associated working hypotheses.

1.3. Version-specific notes

This document is the first version of the deliverable “PIXEL models” (D4.1). This deliverable is written in parallel with the deliverable "Use cases and scenarios manual" (D3.4) on which WP4 is based to describe and analyse the ports’ needs in terms of modelling, simulation and data analysis. That's why this analysis will not necessarily be exhaustive and completed in this deliverable, but this document gives the first elements on this subject. The full technical description of port-operation processes to model will be in the second version of this deliverable (D4.2).

In addition, this document is written before the deliverable "PIXEL Requirements Analysis" (D3.2). Thus, all the elements relating to the characterization of the data available for the implementation of the models and data analysis are not fully available for this first version. This also has an impact on the precise definition of the models used in PIXEL: for example, model accuracy and scope are greatly related to quality of data. This document provides the first elements on these points and will be completed in the second version of the deliverable (D4.2). This first version (D4.1) does not contain any elements describing the concrete implementation of the models. This point will be addressed in the second version of the deliverable as well as the part describing the interoperability of the models.

2. Introduction to PIXEL's models

As part of the PIXEL project, it was decided to develop models and data analysis based on the real modelling needs of the ports. These needs could be divided into the following themes:

- Modelling the consumption and energy production of the port with the aim of moving towards green energy production (Port of Bordeaux).
- Congestion modelling of multimodal transport networks in order to reduce the impact of port traffic on the network and thus minimize associated environmental impacts (Ports of Monfalcone and Thessaloniki).
- Modelling the environmental pollution of the port (dust, air pollutants, noise) with the aim of reducing the environmental impacts of the port on the city and its citizens (Ports of Piraeus and Thessaloniki).

These three themes are obviously related to each other and will integrate and communicate in the context of an environmental management model. This interoperability between models will be fully developed in the second version of the deliverable. As shown in Figure 1, these models will be then integrated as operational tools in the PIXEL infrastructure. All modelling needs from the four ports are described in following sections.

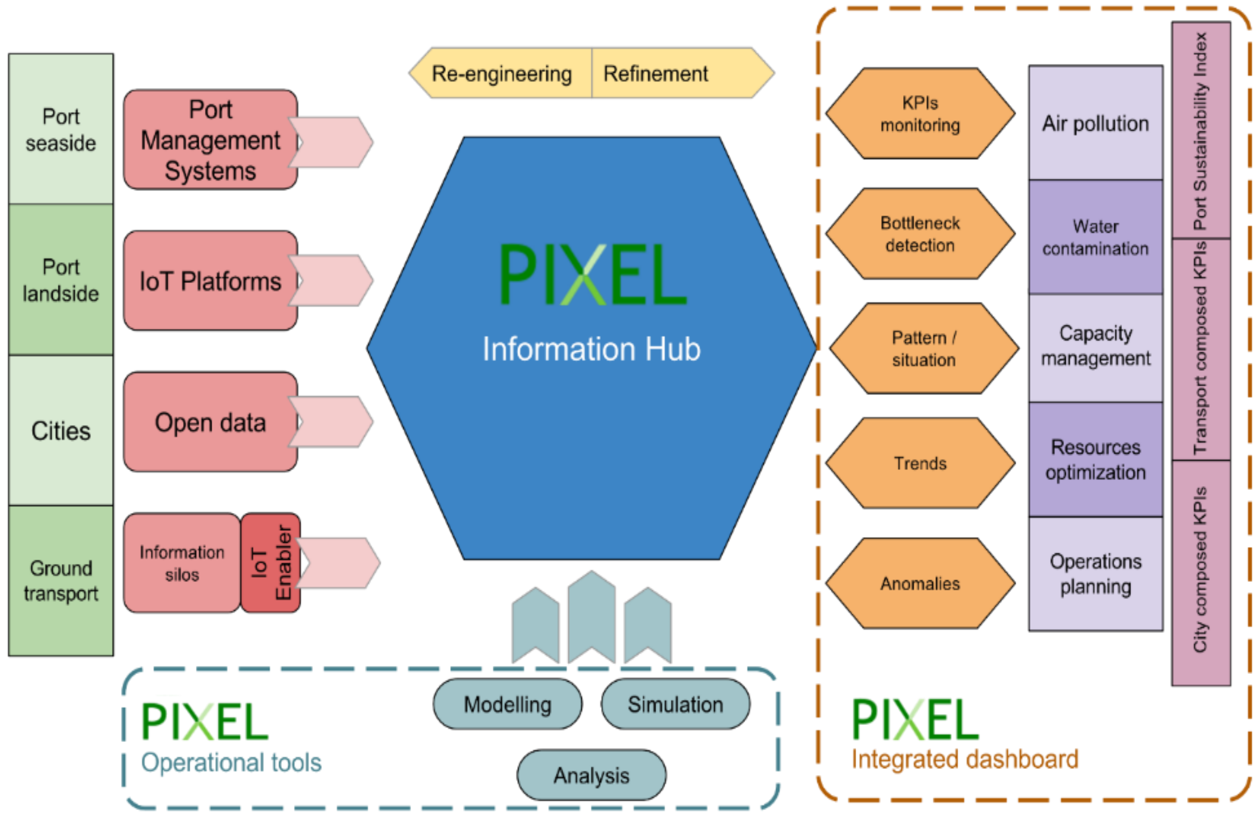


Figure 1: PIXEL ICT Infrastructure

In the following we aim to introduce the roadmap followed for the development and implementation of these models in PIXEL. We also describe the existing links with the other WPs of the project. Then, we define concepts that are common to the entire WP4. Finally, we present the risks related to the development and implementation of these models as part of PIXEL.

2.1. Roadmap

2.1.1. Vision

This section introduces the overall vision and roadmap of the PIXEL's models, through the presentation of some key concepts. This roadmap has been approved by all WP4's consortium partners.

What is the starting point?

Today, European small and medium-sized ports (in the light of discussions with PIXEL's ports and other actions such as DocksThe Future sessions 3rd-7th December 2018) are scarcely equipped with tools to calculate, estimate or predict impacts on energy consumption, transport networks and environmental pollution of port activities. These tools are lacking at the ports in order to put in place decision-making solutions to quantify (even roughly) the environmental impacts of their activities. To provide these tools we argue that two actions are needed:

i) Development and implementation of tools to model the impacts (in terms of energy, transport and pollution) of port activities.

ii) Qualified data coming from sensors, port data, etc. to calibrate, parameterize, feed or develop the models.

PIXEL aims at developing both actions. In this deliverable we present how ports activities can be modelled and how their environmental impacts can be estimated or predicted. We also have a focus on the available data in ports since model quality is greatly dependant on data quality.

What do we want to achieve?

PIXEL's models aim at defining and implementing port's activities models to be used in order to manage the port in an efficient way and adapted to the environmental needs, including energy demand and production, hinterland multimodal transport, atmospheric and noise pollution.

In order to achieve this ambitious objective, the steps listed below are followed:

- Elaborate a clear and precise technical description of the port-operation to model (activities catalogue, optimization parameters, scope definition).
- Establish a list of data available in ports in relation with the port-operation to model. These data will be qualified in terms of accuracy, frequency, representativeness, etc.
- Choose, develop and implement the best approaches depending on the available data (selection of an adequate level of details). Some data has already been provided in the context of WP3 (D3.3 and D3.4), but the level of detail required in WP4 is higher for a complete description of the models and their output expectation depending on the input data.
- Defining links between the different models.
- Define a methodology to evaluate environmental impacts based on energy demand and production models, hinterland multimodal transport models and atmospheric and noise pollution.

The vision of PIXEL's models can be summarized using the diagram shown in Figure 2. Eventually, port activities models will be fed by data from the PIXEL Hub. Each port activity will be described by a scenario of its own. Depending on the data available via the PIXEL Hub, this scenario will be completed with models related to energy, transport and environmental pollution. The goal is to quantify the impacts of a scenario and / or allow the end user to derive recommendations.

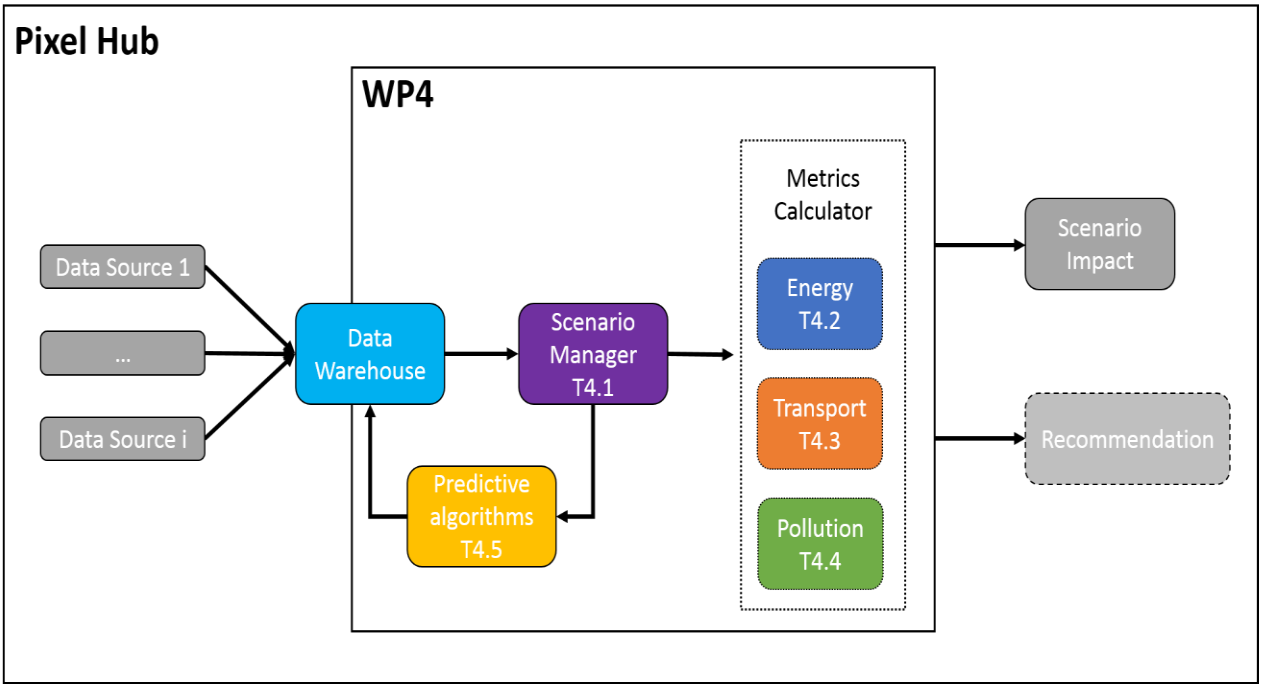


Figure 2: PIXEL's models current vision

In PIXEL WP4 we have also identified some points of convergence with the Port Emission Toolkit (GloMEEP and IAPH, 2018) and we share some common ideas:

- GloMEEP has already worked on how to plan a port emissions assessment and has proposed a methodology for selecting pollutants, emissions sources, geographical and operational domains, temporal period and frequency of the inventory. This methodology could be adapted for small and medium ports and PIXEL can contribute with a methodology to move from an emissions inventory to an environmental assessment of ports through a single, intelligent and adaptable indicator that will be the PEI. This last part is mainly addressed in WP5.

- They have also defined some key elements as activity data. This has been already discussed by the PIXEL consortium. This approach can be used to have average data related with port activities.

- In the Port Emission Toolkit, they focus on port emissions and give a full methodology to have a comprehensive emission inventory (emission factors, activity data) not only for seagoing vessels but also for cargo handling equipment, on-road heavy-duty vehicle, rail locomotives, and electrical grid emissions. They also give some metrics for equipment, activity and emissions. This could be used as a basis for PIXEL models which will be an added value of what GloMEEP has proposed by allowing the prediction of some environmental impacts.

- GloMEEP could also be interested in working with European ports as they state "There is a heavy reliance on US port information in this document. This is because several ports in the US have undertaken port emissions assessments and because published information from other ports on the subject is limited".

2.1.2. Purpose

WP4 goal is to provide several Pixel Modelling Tools to the Pixel Hub. Indeed, WP4 will propose models, data analysis and algorithms in order to manage port in a more efficient way and adapted to the environmental needs.

To do this WP4 considers the environmental impacts identified in WP5 as necessary to the Port Environmental Index and tries to provide raw metrics through an emissions quantification. Then in WP6 (especially in T6.4 Pixel Operational Tools) those models, data analysis and predictive algorithms will be integrated through the software operational tools. Thus, WP4 proposes a clear and validated (meta)model adapted to the needs of ports defined in WP3.

Together these modelling (WP4) and operational (WP6) tools can constitute a decision support tool providing a useful and transversal knowledge for cargo operational management. It will allow operators to evaluate the environmental impact of activities scenario, and to compare them for an optimal choice regarding environment as the primary metric. Our purpose is to develop the different components as shown in Figure 3.

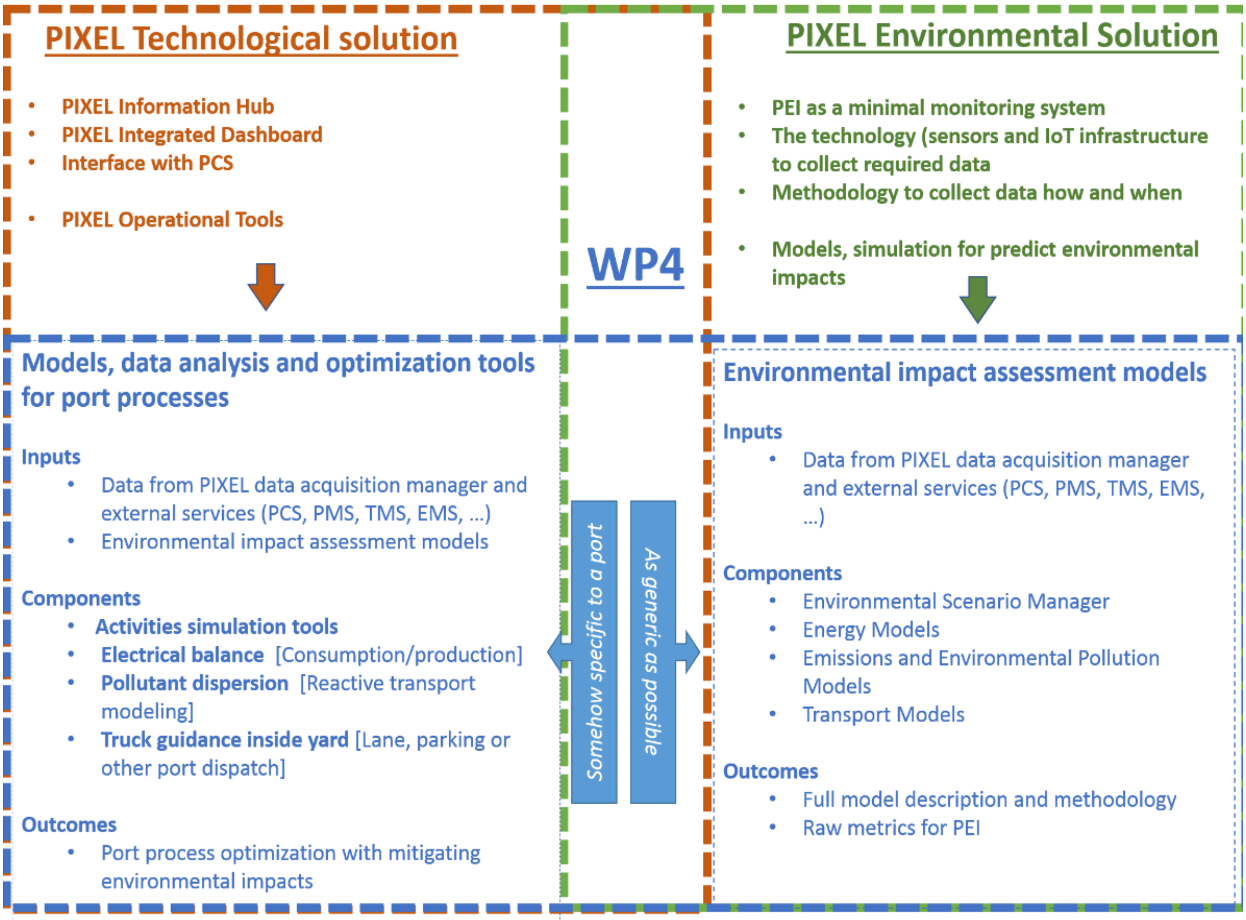


Figure 3: PIXEL Models components

2.1.3. Scope

PIXEL models will consider cargos (liquid/dry bulk, breakbulk, container or passengers) as the functional unit. Therefore, we will study cargos transitions between areas (from sea to hinterland) through transition operations (i.e. unload, load and transport) by machines (e.g. crane, truck etc.).

A specific composition of cargo's transition operations (involving different machines and operators) will be referred to as a supply chain, as illustrated in Figure 4.

The modelling of supply chains applying to different types of cargoes will enable us to correctly identify the energy sources involved, the types of equipment used, the sources of pollution and the frequency with which these cargoes enter and leave the port.

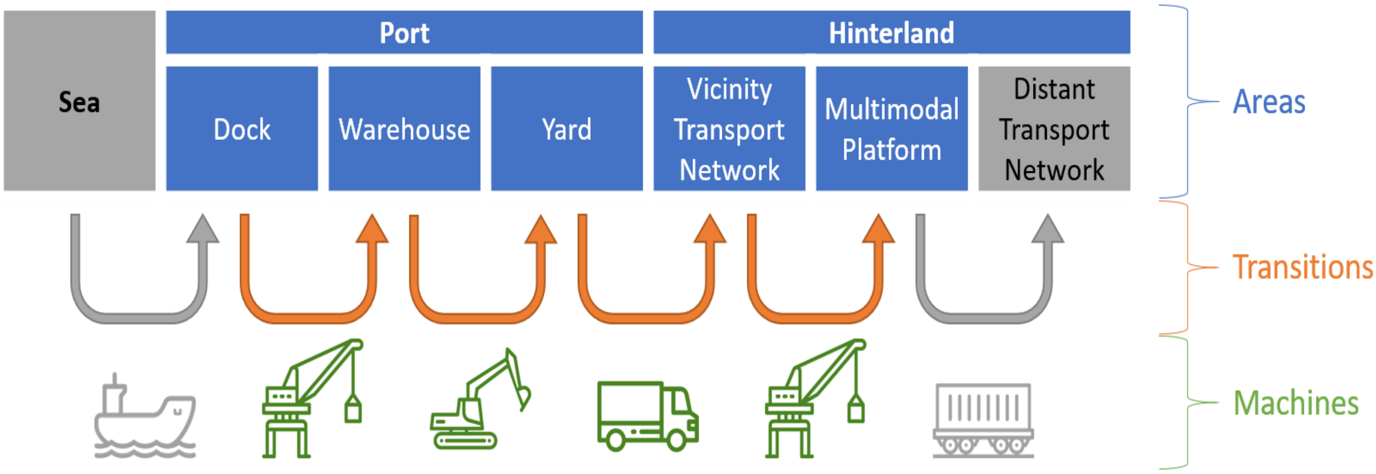


Figure 4: WP4's scope illustration through a cargo's supply chain example. Grey elements are outside scope.

Each model will have its own assumptions and boundaries, but transitions of freighters outside the port ecosystem (for example at sea or in the destination lands of the cargoes) will not be integrated into the PIXEL models.

2.2. Links with others WP

The goal of this section is to introduce the PIXEL models as part of the PIXEL project.

Firstly, we link PIXEL models to WP3 (Requirements and use cases) work and the technical description of the case studies with a focus on data analysis and modelling. We specify the elements resulting from deliverable D3.3 and D3.4 with a clear focus on modelling and data analysis.

Secondly, we describe how PIXEL models will interact with WP5 (Port Environmental Index Development) and how emissions quantifications could be used in the Port Environmental Index (PEI).

Thirdly, we show how PIXEL models will be integrated in the operational tools. The objective here is to highlight the needs and constraints of the PIXEL models towards the data management and overall architecture of PIXEL's operational tools.

Finally, we discuss the link with the implementation and test of the PIXEL models in WP7 (Pilots trials integration, deployment and evaluation) trying to identify the data sources available in the ports as accurately as possible.

2.2.1. WP3: Technical description of ports activities for modelling and data analysis

2.2.1.1. Port of Bordeaux

2.2.1.1.1. Port process description

In D3.3 and D3.4 (Use cases and scenarios manual), GPMB has defined the specific actions of its use case, primarily focused on energy modelling. Given that the use case is located at Bassens, the actions that require modelling are related only to ships dealing with good (Bassens do not manage passengers' calls). Indeed, in order to predict energy consumptions on a port terminal from expected vessels calls, it is needed to analyse the different processes of loading/unloading goods.

In order to cover 100% of loading/unloading cases, 5 different logistics schemes have been described (based on GPMB experience in maritime logistics):

- import/export of containers,
- imports of handled solid bulks,
- exports of handled solid bulks,
- imports / exports of non-handled solid bulks,
- imports / exports of liquid bulks.

It is planned (based on scenarios described in D3.4) that simulation will be able to predict, at least:

i) energy consumption related to ships operations and involved logistics chain,
ii) energy to cover consumption needs of the port (how much green energy the port could provide and anticipate how much will be needed).

The (energy) modelling has to include the following items:

- lightning,
- buildings near the area of loading/unloading ships,

- consumption of different engines of machinery when loading/unloading cargo to/from vessels,
- reefers consumption,
- weather and other contextual information.

If GPMB had all consumptions from all electricity-consuming equipment, the port would not need a model (because energy consumption will be fully derived from electricity measurement sensors). The main goal here is to take advantage of the electricity consumption available, machine specification, and other contextual information to simulate and optimize the balance between energy produced /energy consumed / energy to be bought / energy to be provided.

The component that provides extra value on simulation is also to know how the traffic will be changed, and to know if PIXEL will still be able to model this change and act consequently.

2.2.1.1.2. Modelling needs

The global needs of the GPMB to model and analyse its energy consumption and production are described using users' stories approach. The scenarios are presented in D3.4 but for D4.1 there is a particular focus on the modelling needs.

As an **energy manager** (or **energy supplier**), I want **to assess the relevance** of a new activity for a port which is **"green electricity supplier"**.

To do so, I want **to know if electricity storage infrastructure (batteries) are needed** and if all **the needed investments (works to reinforce the rooftops, solar panels, electricity network) will be profitable** depending on the market price of electricity.

As a **port operator,** I want **to assess if purchasing green electricity from the port brings added value to my activities** (lower costs, environmental-friendly behaviour...).

In order to achieve these global needs modelling and data analysis will be focused on ships operations to predict energy consumptions – both models and predictive algorithms could be used depending on the level of accuracy of the information in possession of GPMB for each case – on a port terminal from expected vessels calls and on energy production using solar energy. We will focus on this point because having the ability to predict the energy consumption due to the arrivals of a specific cargo will help the port to better plan its energy use.

Another point to focus, is the modelling of the energy production trough solar panels. If we want to assess the possibility that the port can be a green electricity provider a prediction/ simulation of the energy production capacity is needed.

These needs are described with the following users' stories.

Modelling the energy consumption

As a **statistics manager,** I want to **analyse the structure and periodicity of ships calls** from the internal database including notions of time of call, goods, tonnages, berth, etc, so that I could **estimate the average call time of a targeted good** taking into account the wharf and a potential seasonality.

This is a first step to do because energy demand (trough the supply chain) directly depends on ships calls. This analysis will help the port to better understand its activity and then its energy demand. For now, this information is already available in GPMB database but not yet analysed. The loading / unloading rate is not the same for a similar good on a wharf (for instance grains) especially due to crane or conveyor belt used. Seasonality is also important since for a same good, ships are bigger or not depending on harvest season or not. Information in the database owns by GPMB should allow to identify these parameters

As an **energy manager,** I want to **evaluate the energy consumption of each logistic chain model identified** by using measurement or approximation of the consumption of each element relating to loading/unloading considering technical features**,** so that I could **determine the relative share of each energy in the targeted logistic model and identify the potentially interesting elements for renewable energy injection**.

This is the second step of the modelling part. We want to model the supply chain for different types of cargo based on machine specifications and activity. We aim to be able to estimate in advance (a day or a week) what will be the energy consumption due to loading/unloading boat. This will help the port to better plan its energy use.

As an **energy manager**, I want to **link the results of modelling**, namely: ships call data analysis and energy consumption of the logistics chains, so that I could **determine the energy consumption of any ship that has called** in the past and estimate the likely energy consumption of future ships whatever their goods.

This data processing will allow other features such as predicting the energy consumption of a vessel that has never called at Bordeaux by considering the parameters mentioned earlier as the size of the vessel (in taking a similar vessel) with tonnage and goods. These extrapolations and analyses will enable GPMB to determine in advance a reliable range of energy consumption.

As an **energy manager**, I want to **analyse the distribution structure of electrical energy from sensors available** on the entire terminal, so that I could **study from a data collection platform the consumption structure of all or part of a targeted area** in order to distribute the adequate proportion of electricity according to needs.

Today smart sensors are available at Bassens but they have to be connected to a platform that can gather and analyse data. The objective is to have a data analysis (based on past data) in order to predict the energy consumption of terminal operators.

Modelling of the energy production

As an **energy manager**, I want to **predict the conditions of sunshine in advance using a weather station** positioned on the wharf, so that I could **determine the amount of solar energy available on a ship call and adapt the need of conventional energy** which will be more expansive than renewable. I could also **accurately determine** the handling downtime due to rain or wind type.

GPMB aims to know in advance what will be the potential of energy production using solar panels. This simulation/prediction tools could be based on data coming for external resources, based on a historical data sets or based on results on a weather simulation tools or service. In fact, the station is not designed to predict but to record what happened. This will be used to analyse the gap between tools like PVGIS (http://re.jrc.ec.europa.eu/pvg_static/methods.html) or similar tools estimations and the real situation.

2.2.1.1.3. Data available and/or to be collected

In order to predict the energy consumption of cargo supply chain, PIXEL methodology needs to know the specifications of engine, of cargo of every day of the year, energy production of photo-voltaic panel and weather in the port. This would be the ideal data.

Table 2: Data available and/or to be collect in GPMB

Data needed	Available	To be collected	Means of transmission	Frequency
Estimated costs of works on a warehouse (solar panels, reinforcement of rooftops structure...)	Yes (need to be updated)		Report	Once
Market price of kWh (electricity)		X	Energy marketplace	Daily
Expected calls and type of cargo: - FAL Forms (date of arrival, date of departure, cargos, dangerous goods…)	Yes (from VIGIEsip)		72h/24h prior existing XML messages	Daily

- Statistics on calls - Characteristics of vessels (specific data on engines must be fetched in Lloyd's registries (IMO number is known))			Excel spreadsheet Vessels also with existing XML messages	Daily Daily
Electricity consumption on port premises (every 10 minutes) - Lightning - Building consumption - Reefers consumption	Yes		Means to collect and send them to be defined	Every 10 minutes
Characteristics of engines being used during cargo handling		X	Report	Once
Other fuels consumption		X	Report	Yearly
Amount of kWh produced	Yes		Through existing models (PVGIS for example)	Yearly
Weather data	Yes (from one weather station)		To be defined	Daily or more often (to be defined depending on the station characteristics)

Some data already exits but they need to be updated or collected and some work need to be done before these data can be used in modelling or data analysis. For example, electricity consumption measurements must be precise in terms of representativeness (or measured for each use or aggregated data). These works still have to be done.

2.2.1.1.4. Scope and boundaries of port activities to model

We will focus only on the energy consumption and production that directly depends on the port authority of GPMB. Currently, energy consumption and production of 3rd parties are out of the scope of the modelling and data analysis exercise since GPMB may not be able to have access to their data due to legal issues. Moreover, there is plenty of actors when loading/unloading ships goods. This clearly presents the scope of primary PIXEL models to be implemented. However, as for D3.4, there is a user scenario that envisions potential transfer to other port agents if they provide their own data. This will be properly analysed at later stages of the project when the deployed models have already been assessed in the pilot trials.

2.2.1.2. Port of Monfalcone

2.2.1.2.1. Port process description

In D3.3 and in D3.4 (Use-case and scenarios manual), the Port of Monfalcone, SDAG and INSIEL have defined the specific actions of their use case.

The activity that should be modelled for the intermodal use-case is an easier and effective methodology in order to be able to find better logistic solutions referring to the connection system between Port of Monfalcone and SDAG (as a parking area and an intermodal terminal). The result of the lack of communication, in terms of both data and decision-making tools, is the difficulty in the re-routing of the trucks towards SDAG or other parking areas or choosing other modes of transport (for example the railway).

What should be provided by the model, is the management of the road traffic to reduce and/or prevent congestions in the port area and so reducing also the environmental impact in the surrounding/urban area of Monfalcone, reducing accident risks and enhancing the management of the parking areas and all other regional infrastructures.

2.2.1.2.2. Modelling needs

The modelling needs of ASPM and SDAG are described using users' stories approach. The scenarios are described in D3.4 but in D4.1 there is a particular focus con the modelling needs.

ASPM

As the **gate access manager**, I want to have **automatic predictions** (on daily basis) **of parking occupancy in the port entry parking area** using the actual parking occupancy, the port gate flows and the vessels scheduling and historical traffic data on a daily basis with "some" hour range so that **truck operators can be notified of congestion of port access and parking availability** / predictions if they overpass certain threshold, as well as other stakeholder (municipality, police), in order to evaluate proper actions to minimize the issue and port-city interference.

ASPM plans to implement a system that will count the vehicles entering and exiting the port. Therefore, it will provide a measure of the parking occupancy. This is still a work to do. At the same time the video system is capable to monitor a defined area of the access road to the port and send an alarm if the trucks are stuck for a certain period of time. It is planned that the data will be available online.

At the same time, the system, in the case the parking area is full (or almost) and the automatic predictions of parking occupancy forecast an increment in traffic flows and parking needs, truck drivers/operators can be notified of it and linked to SDAG in order to reroute their parking destination towards the interport or delay their arrival to the port/parking area. The port cannot oblige a truck to divert its route but only suggest it to stop at SDAG. This information can be shared by PIXEL with SDAG and allow truck drivers to book a parking slot in SDAG facility.

Another aim in Pixel project is to evaluate the externalities (such as pollution, road consumption and the risks related to slabs traffic) related to specific good flows (slabs) and how intermodality can lower them.

SDAG

As a **parking area**, I want to **receive automatic alerts of trucks diverted to SDAG from the Port of Monfalcone** also specifying which type of truck is diverted (for example if it is an ADR dangerous transport) and consequently an automatic booking of our parking lots for the diverted trucks, when available.

Furthermore, I want to **have predictions**, for example through simulations, about **the traffic and congestions in the port/surrounding areas** (through a system that put in communication more stakeholders thanks to SILI platform) so that I can **estimate the number of trucks** coming to SDGA and **evaluate the use of all available resources for the transportation** (for example: railway or re-address trucks in other regional parking areas) to deal with the traffic towards other multimodal transport.

The objective here is, based on the data provided by other stakeholders, predict possible congestions and so route trucks to SDAG by the other roads available or by the railway.

2.2.1.2.3. Data available and/or to be collected

In order to detect and predict congestion and fulfil the use case a list of required data is listed below.

Table 3:Data available and/or to be collect in ASPM and SDAG

Port of Monfalcone				
Data needed	**Available**	**To be collected**	**Means of transmissions**	**Frequency**
Arrival and Departure time of ships to the port of Monfalcone		X (from PMIS – Port Management Information System)		
Actual and historical traffic data through the port of Monfalcone access gate	Yes (from SILI system)			
N° of free parking lots / Full parking lots	Yes (a video system has to be installed by ASPM to record this data)			
Congestion presence on the road to the port of Monfalcone access gate		Yes (a video system has to be installed by ASPM to record this data)		
Traffic information / congestions along the regional road network		X (from other stakeholders: i.e. Autovie Venete)		
Truck company contact data	Yes (from SILI system)			
Traffic statistics	Yes (from ASPM)			
SDAG				
Data needed	**Available**	**To be collected**	**Means of transmissions**	**Frequency**
N° of trucks diverted to SDAG		X from Port of Monfalcone	When trucks are leaving the port	When trucks are diverted
Arrival and Departure time of trucks to SDAG		X From Port of Monfalcone	When trucks are leaving the port	When trucks are diverted to SDAG / are leaving from SDAG

			When trucks are entering in SDAG / leaving from SDAG: SDAG Access control system	
Type of trucks diverted to SDAG (for ex. ADR)	Yes in SDAG (when trucks entering in SDAG there is a video-surveillance and access control system able to read plates and and Kemler codes to detect the type of dangerous goods transported)	X (when trucks are diverted to SDAG, we need the information from the Port of Monfalcone)	When the truck is entering in the parking area of SDAG: SDAG Access control system / video surveillance	When trucks are diverted to SDAG / are entering in SDAG
N° of free parking lots / Full parking lots	Yes in SDAG (for the concrete methodology of connecting our system to the pixel platform to get the information we should first consult our supplier)		SDAG Access control system at the entrance of the parking area	Real time
N° of free places on the train for trucks diverted to SDAG		X (from other stakeholders)		On demand when the railway is identified as the best solution for diverting the truck
Traffic information / congestions along the regional road network		X (from other stakeholders: i.e. Autovie Venete and FVG Strade)		Daily / For particular peaks of traffic: when needed

2.2.1.2.4. Scope and boundaries of port activities to model

The model will help to understand if a different traffic management has a positive impact on congestions issues, citizens risk on the road and environmental impacts. The main result that will be reached is an effective decision support tool to optimize the re-routing of trucks from the Port towards SDAG or other infrastructures, and so facilitate the staff working in both entities.

To model congestion inside port area we need to understand how vessels through incoming and out coming activities influence trucks flow inside port area. In a nutshell, how many trucks are needed to move cargo inside vessels incoming and outcoming.

Models will also consider trucks entering and exiting port, and of course the real time situation of parking occupancy.

There are also external factors to consider, such as weather situation, road congestion and traffic limitations due to Authority's order. These factors influence port access availability (input and output) eventually triggering the diversion of incoming trucks from ASPM to SDAG.

So, the models should be able to overlap different kind of data in order to extrapolate the amount of trucks which need a free slot on parking area. Data needed are depicted below:

- Planned arrivals and departures of vessels;
- Planned arrivals and departure of trucks;
- Real time parking occupancy;
- Real time situation on port's gates.
- Weather situation;
- Road traffic situation (include Authority's order).

To model how the vessel's loading and unloading activity influence trucks flow inside the port area and especially how this flow is related to slot parking demand we need to analyse historical data.

Real time parking occupancy and real time situation on port's gates (trucks stuck in the queue waiting to enter the port) give us an immediate picture of parking situation at a certain time.

Planned arrivals and departure of both vessels and trucks give us an idea of near future parking slot demand.

Overlapping data explained above and applying predictive algorithms (tuned by analysing historical data) the model should be able to simulate trucks flow inside port area and forecast parking slots demand.

Combining this information with real time information about parking occupancy the model will be able to identify any critical situation eventually triggering diversion of incoming trucks from ASPM to SDAG.

2.2.1.3. Port of Piraeus

2.2.1.3.1. Port process description

The process that will be modeled is the noise and air emissions from the container terminal and passenger /cruise terminal activities respectively. The PPA port complex is the nation's largest passenger and cruise hub and includes its busiest container port complex. In this research effort, the noise distribution at the port of Piraeus needs to be addressed via modeling the following activities:

- Co-evaluate in combination with the results of LAeq indicator measurements in order to have adequate data for noise mapping in the residential area.
- Estimate the noise level impact of the Container Terminal in the residential nearby area.

The following issue are not directly related to modelling, but they may be addressed in parallel:

- Determination of the main sources that dominate the noise emitted by ships during port condition.
- Overview of the possibilities to attenuate the noise sources with technical solutions.
- Assess the key noise source in the area.
- Determine the noise levels per activity fluctuation during the period of study.
- Estimate the influence of the air emissions related with the port activities (cruise and passenger terminals) at the city.
- Have predictions for the effect at the city (emissions alarm mapping) by the air emissions associated with the cruise and passenger Terminal.

2.2.1.3.2. Modelling needs

As an **environmental operator,** I want to develop **air pollution dissemination models** using air quality measurement and meteorological data. I also want to have **predictions of pollution impact on the city coming from cruise and passenger's ships related activity**.

Cruise and passengers' ships, and the large amount of associated bus and taxi traffic that transport cruise/coastal shipping passengers to and from tourist destinations and islands in the area, are one of the most problematic pollution sources by members of the PPA community.

As an **environmental operator**, I want to **estimate the noise level produced by port activities** in the container terminal so that I can **have predictions of noise level impact on the city** coming from the container terminals.

In order to be able to have an adequate data set for noise mapping and accurate estimation of the noise impact of the container terminal in the residential nearby area, PPA need to establish a noise monitoring network with suitable sensors for 27/7 measurements of noise indicator. This will be exploring in the following works in PIXEL.

2.2.1.3.3. Data available and/or to be collected

The availability of data for the modelling needs are listed in Table 4 and consist of three main categories:

1. External data sources:

- Meteorological data form:
    - http://www.meteo.gr/index-en.cfm
    - https://opendata.ellak.gr/2018/02/06/anichta-meteorologika-dedomena-stin-ellada/

- AIS real time vessel traffic monitoring data (sources: https://www.marinetraffic.com/)
- Public transport data from:
    - http://www.stasy.gr/index.php?id=1&no_cache=1&L=1
    - http://www.oasa.gr/?lang=en

2. PPA IT systems:

From the ORAMA ERP and N4 EXPRESS PPA system the following data will become available:

- Input data of containers, cargo and Ro-Ro;
- Output data of containers, cargo and Ro-Ro;
- Cruise arrivals/departures;
- Cruise planning per date;
- All domestic passengers per ship and month;
- All vehicles (except commercials) per ship and month;
- Ships arrivals and departures;

3. PPA field measurements:

- Air quality data:
  An Air quality station has been installed and is under full operation in 24/7 mode. The monitoring indicators are: -CO, BTEX, NOx, SO_2, PM_{10} and meteorological data. The monitoring program is been implemented in collaboration with the National Technical University of Athens since 2009. The data are available in excel form (24/7 per month) archives and in annually evaluation report.
- Noise data:
  LAeq indicator, derived from 2 set of measurements per year in 25 spots around the port.

Table 4: Data available and/or to be collect in PPA

Port of Piraeus				
Data needed	**Available**	**To be collected**	**Means of transmissions**	**Frequency**
Input data of containers cargo and Ro-Ro	Yes		N4/EXPRESSJ/ CARGO_IN.XLS	Following month
Output data of containers cargo and Ro-Ro	Yes		N4/EXPRESSJ/ CARGO_OUT.XLS	Following month
Cruise arrivals/departures	Yes		ORAMA ERP	Following month
Cruise planning per date	Yes		ORAMA ERP	Following year(s)
All domestic passengers per ship and month	Yes		ORAMA ERP	Following month

All vehicles (expect commercials) per ship and month.	Yes		ORAMA ERP	Following month
Ships arrivals/departures	Yes		ORAMA ERP	Following month
Ships arrivals/departures	Yes		ORAMA ERP	Near real time
NO_x, SO_2, CO, O_3, PM_{10}, BTEX	Yes	Yes	excel form (24/7 per month) archives and in annually evaluation report	Semi-annual and annual reports
LAeq indicator	Yes	Yes	Word files	2 set of measurements per year in 25 spots around the port.
Weather data	Yes	Yes	Real time by external source	Real time https://opendata.ellak.gr/2018/02/06/anichta-meteorologika-dedomena-stin-ellada/
Vessel traffic monitoring	Yes	Yes	Real time by external source	Real time/https://www.marinetraffic.com/
Public transport data	Yes	Yes	Real time by external source/open	Real time

Some data could be missing due to a lack of the tools. PPA will tried to fill them through PIXEL:

- Noise levels: there is no permanent network operated. The noise measurements are available in semiannually base.
- Air quality: there is a permanent air quality measurement station that is operated in Passenger Terminal area. There is need for enhancement the network with a station covering the cruise terminal.

2.2.1.3.4. Scope and boundaries of port activities to model

The scope of the PPA model is to create a noise model and a pollution model with the establishment of baseline levels for both models that through the PIXEL Hub and the PIXEL Dashboard will run generic and custom simulations for noise and pollution parameters.

2.2.1.4. Port of Thessaloniki

2.2.1.4.1. Port process description

The process that will be modelled is the environmental impact of truck flows and the use of mechanical equipment for port operations, as well as the extend of it to the city. The main activity is the truck flows (in/outbound) through the Port's main gate (Gate 16), the use of mechanical equipment (forklifts, loaders, etc.) in order to serve the traffic (loading / unloading), the quantity of emissions caused by operating and the extent to which the aforementioned operations contribute to the overall air and noise pollution of the city of Thessaloniki.

From the time the truck enters the port, its dwell time in ThPA premises, use of equipment in order to serve the traffic, up until the exit of truck from the port, we need to have an estimation and visualization of the quantity of the emissions caused, as well as its dispersion in the air according to weather conditions and, if possible, the contribution of the port to the overall pollution of the city. In that way, ThPA personnel will be able to make scientifically based decisions on everyday operations, such as personnel and machinery allocation, reduce number of operations, etc.

2.2.1.4.2. Modelling needs

As **terminal operator personnel**, I want **to estimate the air pollution impact of bulk cargo operations** to the city due to specific/bad forecasted weather conditions, for the next day so that we can **make decisions to decrease the impact**.

Also, due to the unique characteristics of handling bulk cargo, Environmental Operator Personnel need to have an estimation of the air and noise pollution impact of operations (truck flows, loading / unloading – operating machinery) to the city because of specific/bad forecasted weather conditions, so that they can make decisions in order to decrease the impact (sprinkling, reduce number of operations, etc.). The most prevalent pollutant to take into consideration is the PM_{10} particles. In order to visualize the quantity and parts of the city that are affected, a dispersion map is required.

As **terminal operator personnel**, I want to **estimate the air pollution impact of handling carg**o to the city due to specific/bad forecasted weather conditions, for the next day so that I can **have a clear picture of the quantity that adds to the pollution of the city and the parts of the city that are affected** by port operations

Environmental Operator Personnel need to have an estimation of the air and noise pollution impact of handling cargo (truck flows, loading / unloading – operating machinery) to the city, due to specific/bad forecasted weather conditions, on an hourly / daily basis, so that they have a clear picture of the quantity that adds to the pollution of the city, as well as the parts of the city that are affected by port operations. In order to visualize the quantity and parts of the city that are affected, a dispersion map is required.

As terminal operator personnel, I want to **estimate the amount of noise from operating machinery for handling cargo** (loading / unloading) so that I **can have a clear picture of the quantity that adds to the noise of the city and the parts of the city that are affected** by port operations

The final outcome (model) should be a combination of all the above. The expected precision in terms of space, is in meters or kilometres of the distance between the main field of port operations and the city. The expected precision in terms of time is, if possible, on an hourly / daily basis.

2.2.1.4.3. Data available and/or to be collected

The minimum sets of data we need in order to provide useful answers to the modelling objective, are:

- Number of trucks entering daily ThPA's premises, dwell time, engine types, fuel consumption, emissions / noise.

- Number and type of mechanical equipment to unload/load truck; Dwell time, engine types, fuel consumption, emissions / noise.
- Spatial data regarding berthing areas (areas of loading/unloading), ThPA's premises, position of sensors.
- Meteorological data; wind (velocity/direction), temperature, rain, relative humidity.
- PM10 emissions from machinery usage, truck flows[1].

ThPA has data on the entry and exit of trucks, through RFID recognition tags. The time a truck remains inactive (engine shut) inside ThPA premises cannot be identified. As for the types of engines and fuel consumption (thus emissions caused by its operation), indicative data can be acquired through logistic companies, however assumptions need to be made, based on official documentation, worldwide bibliography and standards. The same stands for machinery usage (e.g. DGMR's SourceDB). Finally, ThPA is investigating the probability of installing new noise sensors. In addition, more data can be acquired through the City's Traffic Management Centre, so as to evaluate the traffic congestion added to the city.

ThPA will provide spatial data regarding berthing areas (areas of loading/unloading), ThPA's premises and position of sensors.

As for meteorological data, ThPA will provide data from its station inside the port's premises, on temperature, relative humidity (%), wind direction and velocity. Meteorological data can also be acquired through public databases (Municipality of Thessaloniki, etc.) of nearby meteorological stations.

Pollution data on various pollutants (SO_2, NO_2, CO, PM_{10}, $PM_{2.5}$) will be provided by ThPA from its meteorological station. Data is gathered 24x7. Also, data from an extra "echo PM" sampler, gathering data on heavy metals in the air, will be provided. Furthermore, pollution data on PM_{10} & $PM_{2.5}$ particles can be collected when needed, through targeted measurements with a portable sensor. ThPA is investigating the possibility of installing another sensor on Gate 16 (entry/exit point of the Port), so as to have temporal and spatial correlation with the time of entry and exit of trucks. Data can also be acquired through public databases (Municipality of Thessaloniki, etc.) of nearby stations.

Apart from the aforementioned sets of data, ThPA has at its disposal data concerning sea water quality, collected every six months with a mobile sampler, from four prefixed points. Moreover, data on electrical consumption are available, for 9 electric substations (mid-voltage). Not all relevant data, only a subset: consumption in KWh, cosine, financial data. Data on fuel quantities are also available.

Finally, no data on pollution or noise deriving from ship's engines are available but based on the type of ship (ThPA statistics, official classification by IMO), time that remains in the port and horse power, conclusions can be extracted.

Table 5: Data available and/or to be collect in THPA

Port of Thessaloniki				
Data needed	**Available**	**To be collected**	**Means of transmissions**	**Frequency**
FAL Forms	Yes			
Entry / exit of trucks (RFID tags)	Yes		Stored in relational database (MySQL)	Real-time.
Wind direction/speed	Yes		Sensor inside ThPA, on GC#3: stored in relational database (SQL Server)	Real-time

[1] https://www.softnoise.com/pd/sourcedb.html

Wind direction/speed, temperature, relative humidity (%)	Yes		Sensor inside ThPA (rooftop of TY building). Export, static files in TXT (needs transformation)	
Electricity consumption #1	Yes		Manual data entry (from monthly electricity bills), for 9 electric substations (mid-voltage). Not all relevant data, only a subset: consumption in KWh, cosine, financial data. Stored in relational database (MySQL).	Monthly
Real-time fuel consumption, RFID tags/sensors on vehicles & pumps	Yes		Stored in relational DB, option to export to static files (CSV,..)	
Spatial data	Yes		.dxf files, .shp files , a (hand-crafted) KMZ (GoogleEarth) with “points-of-interest” inside THPA premises (ie location of met stations)	
Pollution data #1: PM10 & PM2,5	Yes		From TSI8530 (portable handheld PM analyzer) used inside ThPA. Data downloaded locally in XLSX format	
Pollution data #2: Various pollutants (SO2, NO2, CO, PM10, PM2,5) from met station inside ThPA	Yes		Sent (via SIM card) real-time to web logger airmonitors.net (web interface & export, API option mentioned on website). Also installed, a “TECORA echo PM” sampler, 10mins every hour, data gathered once a month, heavy metals in air (mean monthly value)	Gathered 24x7,
Sea water quality	Yes			Every six months sampling of four points, mobile sampler, manual data entry of results
Primary weather data from NMS stations (Athens…)		Yes. Open data.		https://opendata.ellak.gr/2018/02/06/anichta-meteorologika-dedomena-stin-ellada/

Thessaloniki's municipality open data		Yes. Open data.		https://opendata.thessaloniki.gr/el/search/type/dataset
Weather data of stations. Summary per months.		Yes. Open data.		http://meteosearch.meteo.gr/data/kerkyra/2018-10.txt
Thessaloniki's municipality open data on meteo		Yes. Open data.		
Pollution data #3 (from City's sensors, outside ThPA)		Yes. Open data.	Static files for download in CSV, as far back as 1984. No geo-information	http://www.ypeka.gr/Default.aspx?tabid=495&language=el-GR
Electricity consumption #2		Yes. Open data.	Option to download locally in XLS, CSV, PDF. No API for automatic download/import mentioned on site, though.	To enter with THPA account. DEDDIE (ΔΕΔΔΗΕ) is the Greek State grid owner. Real IoT, sensors on electricity meter, consumption every 15' (per substation), 9 substations.
Thessaloniki's city atmospheric pollution. SO_2, PM_{10}, $PM_{2,5}$, NO, CO, NO_2, O_3…		Yes. Open data.	.xlsx format. Archive from 1989 to 2016. DCAT compatibility. Also available in RDF and JSON.	https://opendata.thessaloniki.gr/el/search/type/dataset

2.2.1.4.4. Scope and boundaries of port activities to model

Due to the port's size and proximity to the city, the aim is to visualize the amount of pollution caused by port operations, primarily by trucks entering/exiting the port premises and the associated machinery used, as well as the areas of the city that are affected by it. The scope is to fuse the available information to have an overall picture on congestion hours and pollution created, so as to achieve optimum allocation of the equipment, trucks and personnel, thus decreasing the Port's environmental impact on the city.

2.2.2. WP5: Environmental impacts measurement for ports activities

According to the Port Emission Toolkit (GloMEEP and IAPH, 2018.) emission inventories “catalogue the various port-related emissions sources and their activities, translate those activities into energy consumption levels and then translate energy consumption into emissions. They provide insight on activities and related emissions of the various source categories, within defined geographical, operational and temporal domains”.

In order to set the stage for deploying the Port Environmental Index (PEI) an inventory of emissions will be built for each of the ports under T4.4.

Although the idea behind PEI is to assess the impact that a port is having on its environment in retrospect, an interesting development which could be incorporated is the forecasting of PEI. This would necessitate providing emissions forecasts based on energy consumption forecasts. The forecast would enable ports to adapt their operational parameters in order to decrease their impact on the environment.

The specific type of emission inventories built will depend on the identification of the significant environmental aspects by the ports. However, based on the current understanding of the problem the following emission inventories will likely have be built for the ports:

- emissions to the atmosphere,
- emissions to the seawater,
- noise emissions,
- production of waste,
- light emissions.

Except for light emissions pollution, these items are identified in the top 10 environmental priorities of the ports in 2018 (ESPO environmental Report of 2018). Regarding the specific inputs for PEI, these will be based on the KPIs which will be identified for each significant environmental aspect.

2.2.2.1. Indicators

2.2.2.1.1. Emissions to the atmosphere

For the emissions to the atmosphere a list of potential KPIs could look like this:

- sulphur dioxide (SO_2) emissions,
- particulate matter (PM) emissions
- nitrogen oxides (NO_2) emissions,
- greenhouse gasses (GHG) emissions,
- emissions of volatile organic compounds (VOC),
- carbon monoxide emissions (CO).

In ports there can be found both stationary sources (e.g. industrial boilers) and mobile sources (heavy and light-duty vehicles, vessel, etc.). All these sources are mostly point sources and usually are modelled as such in case there is a modest number of point sources. However, since in ports there are many point sources distributed over an area, we suggest modelling the emissions in the aggregate, for the whole port.

The emissions in the aggregate for the whole ports will have to be expressed per unit cargo. Since the emissions will be expressed in the aggregate for the whole port a method has to be established to allocate the emissions expressed in the aggregate to the cargo.

For example, if a port handles 100.000 TEU and 50.000 tonnes of bulk cargo per year and it emits 1000 tonnes of GHGs per year the question is how to allocate the 1.000 t of GHG emissions between TEU and bulk cargo. This have to be done in order to properly compare ports with each other. Indeed, regarding PEI all the emissions will have to be expressed per unit cargo. Absolute values are not representative since bigger ports will have higher emissions because they handle more cargo. Therefore, in our opinion the best appropriate approach is to express the data per unit cargo.

2.2.2.1.2. Emissions to the water

For emissions to the sea water, the first need is to know how much wastewater is emitted to the marine environment. This inventory can be done by the following listed sources:

- Port authority (sanitation or rainwater networks),
- Terminal operators (industrial process, shipyard or careening area, …),
- Ships (ballast, grey and black waters), etc.

But this simple way of census doesn't take care of the indirect effects of harbour activities on water quality, like the sediment particle resuspension dues to vessels navigation. On this point, GPMB in the Gironde XL 3D (Laborie, 2013 and 2018, Huybrechts) project work on the implementation of a 3D numerical model able to reproduce the hydrodynamic, salinity, sediment transport and morphodynamics of the Gironde estuary and integrating weather conditions such as wind and storm surges. The developed numerical models are the subject of a complete project (with EU support[2]) with complex numerical methods and requiring important computing resources (supercomputer use). This type of implementation and usage complexity does not seem to be suitable for the PIXEL project.

For all the effluents listed, these potential KPIs linked to water quality can be used:

- Total water rejection in sea per activities (m3)
- Suspended matter or turbidity (for each one)
- Salinity
- Hydrocarbons concentrations
- E. coli or fecal coliforms contamination
- Heavy metal concentrations
- Dissolved nutrients (C, N and P)

2.2.2.1.3. Noise emissions

Noise emission will be based on direct measurements. Portable decibel meters exist which are not very expensive, and ports are usually equipped with those. This means that several noise measurements can be carried out at different time intervals and different sampling points.

2.2.2.1.4. Production of waste

Waste production will be estimated based on the data obtained from the waste collectors as well as in-house collected data on separate waste collection. Effort will be made to normalize all data per unit cargo.

2.2.2.2. Geographical emission inventory

Another important issue is to define the geographical and operational domain of the emission inventory. There is a large array of geographical layouts and features of ports and no single geographical definition of the port's domain exists.

A commonly applied geographical domain is the port administrative boundary and we will thus use this geographical domain when estimating emissions. Everything that is inside the port's administrative boundary

[2] https://www.portdufutur.fr/gironde-xl

will be considered as an emissions source whereas everything outside the boundary will not be considered an emission source of the port.

It must be pointed out that when modelling port-city interaction with respect to translating emissions to impacts to the surrounding environment or predicting the concentration of a certain pollutant once it enters the environment, the geographical domain will have to be extended. This will be done in the second step by modelling pollution dispersion which will use emission inventories as an input.

Regarding the level of detail ideally we would conduct a comprehensive inventory of emissions for the four ports involved. Comprehensive emissions inventories are considered the gold standard/best practice since they are based on detailed emissions estimating methods. Obviously, such an approach is much more complex than using screening methods but the uncertainty regarding outcomes is much lower. They are dependent on significant amounts of data which have to be generated by the ports and also the approach limits the use of proxy data.

According to the current knowledge for certain environmental aspects the data resolution is granular enough to allow for a comprehensive assessment to be carried out whereas for other aspects some of the data will have to be derived from proxy data or even scaled using data from other ports.

2.2.2.3. Inputs needed for each sources of emissions

For air and seawater pollution, the following inputs will have to be identified to develop activity-based inventories for air and seawater pollution:

- **Data on emission sources**. This is to detail the characteristics of each emissions sources.
    - Air Pollution: Size or rating of the engine, type of fuel, engine technology, equipment specification, etc.
    - Seawater pollution: Type of effluent (wastewater, industrial process water, rain water discharge, treated water discharge…)
- **Port activity and operational**. We need this data in order to detail activity in terms of hours of operation, number of calls, etc.
- **Data on physicochemical characteristics of effluent and pollutants**: flow, density, pollutant concentration, bacteriological contamination, …
- **Emissions factors or emission data test for** port activities, what is the estimate quantity of effluent or pollutants released to the marine environment and/or atmosphere. These data can be estimated or measured directly (flow meters) before the release to the sea or atmosphere.

2.2.2.4. Environmental impacts of ports and link with the PEI

The environmental impact is strictly speaking not only a function of the environmental performance of a port but of other parameters as well over which the port does not have any control. An example of which is atmospheric stability. Thus, when environmental performance of a port is assessed it must be decoupled from other factors which are not influenced by the ports. Therefore, the KPI of interest which will be used are only the ones that are related to the emissions from the port’s area and will not include indicators of the quality of the port’s natural environment.

PEI will use the data on emissions data related to different KPI which will be established once the significant environmental aspects are properly formalized and identified and will normalize the data, weigh them and integrate them into a single number.

Pollutant dispersion models will not be integrated into the PEI but will allow ports to better understand how pollutants related to their activity impact the City. Indeed, pollution models are more focus on the quality issue that is not directly addressed by PEI.

2.2.2.5. Raw metrics definition

The raw metrics (coming from the results of emission inventories) used in PEI are the following:

Emissions to the atmosphere	Mass of a pollutant per unit cargo
Emissions to water	Mass of a pollutant per unit cargo
Waste production (hazardous vs. non-hazardous)	Mass of waste per unit cargo
Noise emissions	Decibel per unit cargo
Light emissions	Lux per unit cargo or kW of installed lightning per unit cargo

2.2.3. WP6: PIXEL model's integration inside the PIXEL Operational Tools

PIXEL can be seen both as a technological and environmental solution; the former dimension is mainly covered by WP6 activities whereas the latter one by WP5 activities. Obviously, there is some sort of overlap between them and this is the aim in PIXEL: otherwise we may end up with two different systems without giving the environmental aspect the place it deserves for high level decision support systems.

WP4 comes into scene in order to support and provide a grounding level for the previous WPs, as already depicted in **Erreur ! Source du renvoi introuvable.**3. In this chapter we will describe the relationship with WP6 and how both WPs interact and need each other.

WP6 is responsible for drawing an overall architecture that encompasses all necessary components and, therefore, WP4 components. Relevant WP6 components are:

- Data acquisition layer: it provides a means of collecting all heterogeneous data sources and sending them to the PIXEL hub
- Information hub: it represents a communication hub where all data and basic platform services can be consumed
- Dashboard: it mainly represents the User Interface (UI) with the port operators, with some notification and Business Intelligence (BI) features. As frontend, it may potentially integrate other high-level applications.
- Operational tools: they represent a set of (high level) tools to properly analyse the status of the port through simulation and analysis in order to help port operators making better decision in planning and management.

The models developed in WP4 can be considered as basic platforms services incorporated inside the PIXEL information hub. Such services (models) consume in fact part of the data available in the hub as input and generate process optimization outputs providing added value that can be later consumed by high level tools. The operational tools represent direct consumers of such services; one of the tools consists of a simulation engine in charge of simulating environments with the help of WP4 models. This will be better described in the following subsections.

2.2.3.1. Data management

The data needed for the models comes from heterogeneous sources and in various formats. As the models are focused on efficient representation of tasks to simulate, it is important to relieve them from extra burden of processing input data. Therefore, the data acquisition layer, as part of WP6, is in charge of connecting any potential data source to the PIXEL hub, the entry point for WP4 models and any other service that intends to consume data. For example, this data acquisition layer will connect PLCs, IoT sensors, virtual sensors to the hub in a proper way, accomplishing several tasks:

- Authentication: the data source identity must be checked before being accepted in order to avoid data attacks. The communication with the hub must be secured.
- Verification: the generated data must be verified to a certain extent in order to pre-check that obtained values are coherent before sending them to the PIXEL hub. The data in the hub must be reliable.
- Filtering and aggregation: all generated data does not need to be processed and sent to the PIXEL hub, but sometimes a small subset of it. This specially makes sense when working with IoT gateways, which may aggregate data and send a summary result to the upper layers. The data in the hub must be concise and non-redundant.
- Sampling: Every data source generates information with a certain periodicity. Configuring the sample rate for each data source correctly is important and determines network and content traffic.

2.2.3.2. Data warehouse

For each model to be developed in WP4 there is a specific list of input data items that should be available. Though such availability may consist of directly accessing the involved sensor, database, etc., it is more convenient to access all necessary input data through the PIXEL information hub for various reasons:

- Single entry point and discovery: it provides independency from any port implementation as there is no need for the models to store a list of available data. Note that each port may have different data available and it is more practical to configure it once in the hub than configuring everything in each model. Therefore, each model will only have to invoke the discovery service available in the hub in order to look for the necessary data.
- Pre-processing features: Any model (or basic service) may access confidently the required data available in the hub without the need for performing extra processing. Any relevant low-level data process should be performed by the data acquisition layer.
- Common format: the list of available data items is presented in a common data format and interface, as well as the data itself from each data source.

Apart from accessing the data through the PIXEL hub, each model may also require its own database for internal usage as well to provide results. Depending on the architecture approach, the database may reside directly in the hub (multi-tenant approach) or directly in the model in form of a packaged container (multi-instance approach). In relation to the results provided by the models, they may be available directly through the model API (runtime approach) or as a new data item in the hub (background approach).

2.2.3.3. Data manipulation

Every model developed will have its own input and output data. At WP4 level, there will be a global intent of homogenizing the way models are described and therefore provide a basic means of inserting data and getting data. This will allow interoperability among models to some extent.

At WP6 level, one relevant challenge consists in encapsulating models in form of services MaaS (Models as a Service) in order to facilitate the integration at platform level and provide a clear open interface (e.g. Swagger). This will allow better adoption in other ports.

2.2.3.4. PIXEL Dashboard

The PIXEL Dashboard will be the user interface (UI) of port operators to manage all PIXEL services and components. As a subcomponent of it, the operational tools will be in charge of making use of the models generated in WP4. It is important to note that, at the time of writing of this document, the architecture of PIXEL is still being developed and some changes may occur regarding the user interface; however, the interaction with WP4 models is clear and its integration depends on the Operational Tools. One of such tools is the simulation engine accessing the models to perform some analytics. The basic process will consist of the following steps:

- Simulation engine starts: according to a certain configuration (e.g. predict some value, optimize some task, etc.) the simulation engine is launched. Several simulations may be running in parallel.
- Model discovery: depending on the configuration (e.g., transportation, energy), the simulation engine will look up in the PIXEL information hub for available models
- Model execution: the simulation engine invokes the corresponding model(s) and if necessary, prepares additional input data to the model according to its input parameters.
- Model response: The simulation engine obtains the result and processes it in order to achieve the configured objective. Further iterative model executions may occur in optimization processes or comparative tasks.

Even if it is not yet clear how the UI will look like in the end, it seems sensible to envision some draft overview in order to help understanding what a port operator may expect. This is depicted in **Erreur ! Source du renvoi**

introuvable. where the Pixel Operational Tools have been included within a simple Dashboard. Here operators are able to create, execute and see the results of models. In summary:

- Models are created according to a type, identified in WP4: energy, transport, pollution and city. Other models could be potentially added but Pixel is currently limited to this scope.
- Models can have four states: running, finished, stopped and error. Note that models simulate a specific complex scenario and therefore it may take some time until the results are available.
- Depending on their status, some actions can be performed to the models: stop, edit, delete, view results, etc.

Several interactions between the models and the operational tools have been identified:

- For each model type, a UI template must be defined to create the model, allowing to configure activities, input and output parameters
- For each model type, a way of visually presenting results should also be defined. Probably each model will output data in a common format (e.g. JSON), but this has to be converted into a graphical result (e.g. bar chart)

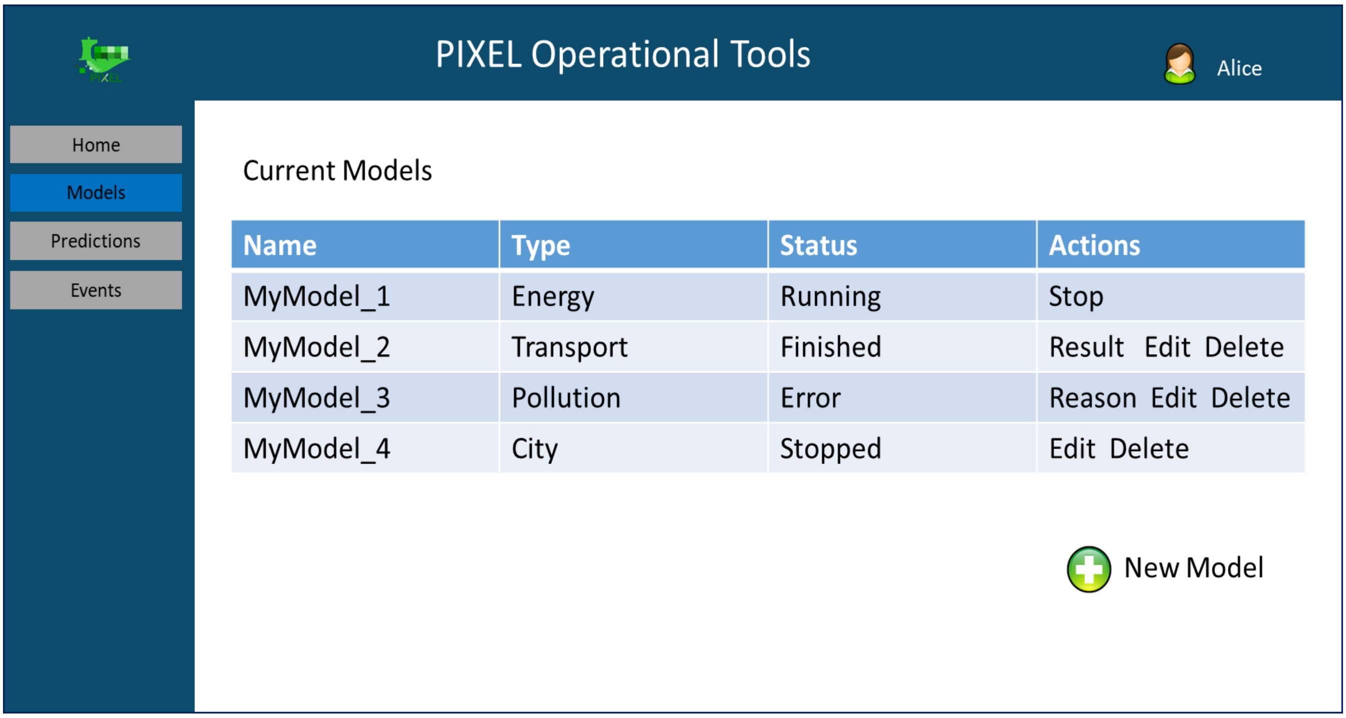


Figure 5:Pixel Operational Tools (initial draft)

2.2.4. WP7: Implementation and test of PIXEL models

After some initial bibliography, a first draft of “standard data map" can be drawn, with the following four data clusters.

Sea to dock: Such data can be provided by FAL forms, Port Management Information System (PMIS) and port’s policy regarding ship announcement. They can bring information about expected & effective arrival/departure time, cargo’s type & quantity (to handle, not total inside ship) or berth allocation.

Dock, warehouse, yard & multimodal platform: Those data seem to be owned by terminals operators. Those data concern cargo supply chain allocation, machines specifications and their availabilities. However, some ports are equipped with CCS (Cargo Community Systems) which aggregate data from different ports stakeholders (terminal operators, freight forwarders, customs, …). It is the case in the port of Bordeaux.

Hinterland gates: Currently the data’s owner is unclear. Those data concern all information about truck drayage (transporter’s expected & effective arrival/departure time, cargo’s type & quantity).

Transportation network (potentially as open data): For roads, the most probable access to data seems to be governments open data strategies. For railroad and rivers, administrator and captaincy seem to be the respective data providers. That information is relative to the transportation network (traffic density, speed, legal or size’s constraints).

2.3. Common definition and notation for PIXEL’s models

2.3.1. Port activity

As we have already said, port activity is generated by incoming and outgoing cargoes in the port ecosystem. Therefore, it seems colloquial to consider cargoes’ transitions as one of the main inputs of models and data analysis.

As a result, the knowledge of the supply chain (type of machine, duration of use, position in the port), allow us to know the energy sources used, local emissions of pollutants but also to estimate the flow of cargoes entering or leaving the port. In this section when we speak about port activity, we refer to the transitions of cargo between the entrances and exits of the port.

2.3.1.1. Activity’s data structure

PIXEL models’ input data are relative to cargos handling from one area to another through machines. This could be seen as a stack of Gantt chart. The Figure 9 shows an example of what an activity data structure looks like.

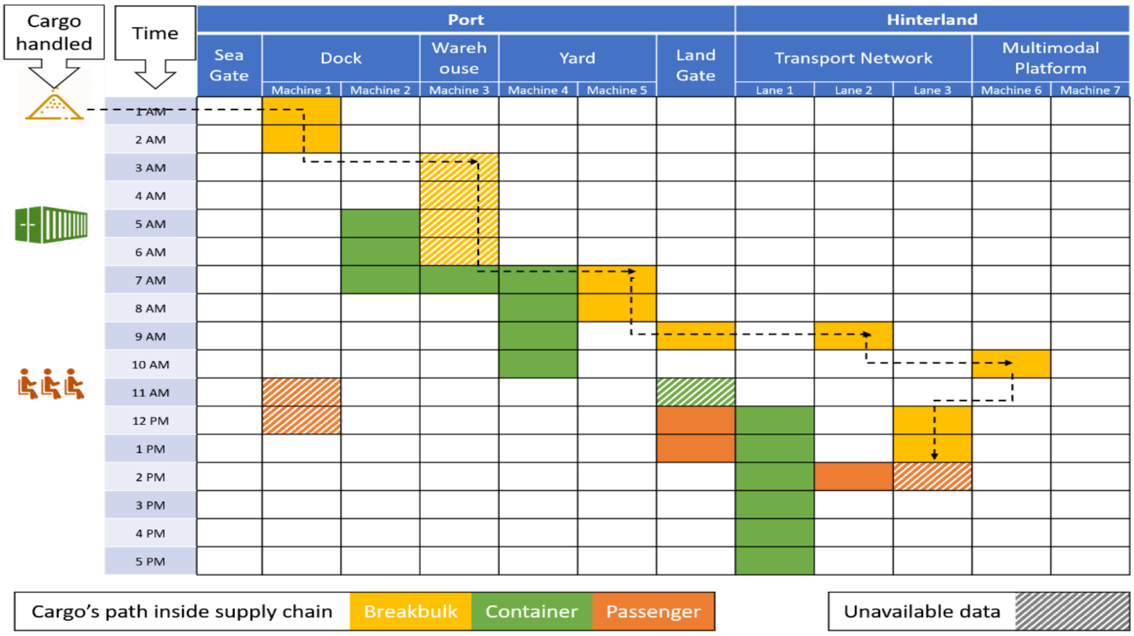


Figure 6: Activity's data structure consists in handled cargo's data projected on time and machine/space axes

The models implemented as part of the project will have as a starting point the modelling of a port operation. This operation will be described in the form of a succession of activities that we will call later scenario. In order to perform a modelling of the port activities, we need to know the types of data described below.

2.3.1.2. Activity data

These data refer to the details related to a transition of a cargo: duration of the operation, type of machine used, distance travelled, etc. These data thus mainly refer to the logistics chain linked to a cargo.

Dock	Sequence
452	{Crane1 > Conv.Belt3 >> ...}
421	{Pump4 > ...}
421	{Pump2 > ...}
310	{Hopper >> Schuller > ...}
...	...

Figure 7: Example of a simple supply chain modelling

2.3.1.3. Operational data / Machine specification

These data refer to the technical specifications of the machinery and equipment used. These data will specify the type of energy used, the consumption according to the mode of operation, the status of the machine, etc.

Machine Specification

Energy	Cons.	Debit	Status
Electric	4.5 (kW)	52 (cont./h)	Ok
Fuel B405	15 (L)	32 (T/h)	Ok
Fuel H56	28 (L)	125 (m^3/h)	HS [dates]
Electric	31 (kW)	32 (T/h)	Ok
…	…	…	…

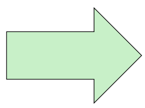
Figure 8: Example of a simple machine modelling

2.3.1.4. Emission source data / Emissions factors

These data detail for each machine, engines or other sources used in the transition of a cargo, the sources of emissions linked to it. These data are very often obtained and based on emission factors allowing to pass from a consumption of energy to a quantity of pollutants emitted.

Machine Specification

Energy	Cons.	Debit	Status
Electric	4.5 (kW)	52 (cont./h)	Ok
Fuel B405	15 (L)	32 (T/h)	Ok
Fuel H56	28 (L)	125 (m^3/h)	HS [dates]
Electric	31 (kW)	32 (T/h)	Ok
…	…	…	…



Emission unit

Noise (dB)	CO_2 (g/h)	PM_{10}	…
75	235	75	…
81	203	81	…
78	178	78	…
87	368	87	…
…	…	…	…

Figure 9: Example of a simple emission quantification modelling

2.3.1.5. Vessel planning

These data refer to the vessels arriving at the ports with the description of the type of cargo, the tonnage, their expected date of arrival and departure. These data thus make it possible to know the expected flow rate for each type of cargo.

Boat Planning

Start	Type	Tonnage
16/05/18 12:15	Cereal	6502
25/05/18 23:06	Sol.Bulk	15284
29/05/18 16:32	Sol.Bulk	751
02/06/18 05:57	Liq.Bulk	6548
...	...	...

Figure 10: Example of boat planning

Although these data alone are not enough to implement all PIXEL models, they will be necessary and common to all and could be considered as a requirement for PIXEL models. Such information can be extracted for example from:

- FAL forms,
- PCS,
- Literature review,
- Analysis of port activities, etc.

2.3.2. Scenario

For each cargo, there are several ways to arrange transition operations between areas. A hypothetical combination of those transition operations (for one or more cargo) will be denoted as a scenario. This scenario will be designed by port operators and the end-users of modelling and data analysis tools. In PIXEL we do not have terminal operators to provide useful information about cargo operations and therefore we will rely on port operations. WP4 aims at providing the ability to get environmental impact metrics for a scenario, and to compare it with alternative scenarios. Thus, PIXEL modelling tools could be used to order or evaluate scenarios according to an optimization metrics.

2.3.3. Activity’s data simulation

Data is a key point in order to have useful models and data analysis and data collection is an intensive phase. Models and data analysis can be developed using different levels of details regarding data. Indeed, depending of the purpose of modelling and the expected precision, inputs data could be less or more detailed. As define in GloMEEP and IAPH, 2018, we also consider the following types of data.

2.3.3.1. Scaled data

These data use approximations to obtain an order of magnitude corresponding to the types of activities considered. These data are obtained by integrating external data produced by a port having a similar activity and representative of the real activity that is to be modelled. The use of this type of data assumes that port activities are similar and should be adapted, for example, to port traffic. The results obtained using this type of data will also be approximate. Therefore, the results of the models based on this type of data have the following features:

- Average and non-specific input data for model port activity.

- Results based on an adaptation according to scale parameter (for example maritime traffic).
- Results with great uncertainty.

This type of data is useful when no information is available and when we are just interested by having an order of magnitude.

2.3.3.2. Screening data

These data are more detailed than scaled data and use data more specific to the port activity considered. These data use local sources for example on the description of the supply chain but use external data for emission factors. The results of the models based on this type of data have the following features:

- Some local input data and external data for model port activity.
- Results based on a simplification of some inputs (for example average energy consumption of cranes and trucks).
- Results with significant uncertainty.

2.3.3.3. Comprehensive data

These data are based on the detailed description of the port activity to be modelled with a complete knowledge of the supply chain, machine specifications, emission factors, etc. These data can come from sensors, administrative documents or expert knowledge. These data will yield much less uncertain results but require a lengthy data collection. The results of the models based on this type of data have the following features:

- A detailed modelled of the port activity.
- Results can be verified and validated using some measurement.
- Results with low uncertainty.

To improve missing data management and allow a better activity forecasting, PIXEL models through what we called a predictive activities tool will try providing accurate activity data to ports. This tool could consist of predicting probable cargo's handling operations in view of available data (past & present) for the port itself but also from other ports. These predictive activities tool may also be useful to validate the models against previous known data. At this time, it still difficult to have a complete overview of what this activity simulation tool will look like, but we aim to explore this approach.

2.4. Technical Risks

2.4.1. Models limits and hypothesis

A model is a substitute for a real system. Models are, by definition, a simplified representation of the real system. Thus, they represent only a limited number of features of the real system. Because models are just an approximation of reality, there is a technical risk that the models, developed under certain limits and assumptions, do not fully answer the modelling needs of ports.

Modelling exercises are usually performed in order to (i) understand the behaviour of a system or to (ii) provide forecasts that can inform decision making and policy. But models must be used with precaution. The use of PIXEL models will therefore be possible only within the limits and hypotheses that we will describe later.

A work will be done for each model in order to try to evaluate it somehow (this still has to be defined) in order to set a confidence value. The same work will be done for confidence in data. The objective is that end users can decide on their own if they will use models or not depending of what are their expectations. This will be described in the second version of this deliverable (D4.2). We focus here in the risk's identification.

2.4.2. Data quality and quantity

PIXEL models and data analysis are based on ports activity's data. That is why models' results is limited to the input data quality. This is a major risk for modelling tools final utility.

Four main data issues type have been identified and must be characterized for each port.

Lack of data: To use statistical tools, build adapted models or train predictive machine learning algorithms, the starting dataset should be large enough. Currently some of the provided datasets seem to be rather small to give a good confidence on activity's data representation.

Incomplete data: For a given cargo's supply chain, there will be probably some unavailable data (e.g. no date for cargo take away by carrier, no information about a specific engine, etc.). This should not result on model crash but should rather lead to a warning to the user. One answer to this issue may be to complete the supply chain's missing data with simulated or predicted data.

Fluctuating data: The data describing activities will probably be frequently updated (e.g. an arrival date, a machine assignment, etc.). Modification "on the fly" should not lead to long recalculation for a minor data's update. This means avoiding whole recalculation when possible, by isolating recalculation on initial and updated data's difference.

Fuzzy data: For some data, there is probably a noticeable uncertainty which varies across time (e.g. uncertainty about a vehicle's arrival hour should decrease with time). At first, pertinent safety margin should be determined for such data input. In a second time, a "fuzzy logic" approach may be required for handling such inputs with uncertainty function of time.

2.4.3. Specificity versus generality

Models and data analyses are carried out based on the different PIXEL's use-cases. There is therefore a possibility that the model developed is too specific for the use-case and therefore not generalizable because requesting hyper-specific data. On the contrary, with a generic model we take the risk of not being able to answer the modelling objective of the use-case.

2.4.4. Port's organization heterogeneity

The targeted ports in PIXEL are organized differently, some partners are operators and others not. This can play a major role on the available data and the possibility of feeding the model with good data. So, there is a risk associated with this heterogeneity for the generalization of the models developed in PIXEL.

2.4.5. Optimization recommendations

Ports have highlighted that sometimes there is a lack of control regarding cargos handling. Moreover, in most situations, there is an imperative priority to minimize ship immobilization duration (first in first out order).

In other words, there is a lack of degree of freedom about schedule or organization modification for environmental impact optimization. Thus, for several WP4's tasks, only knowledge of environmental impact can be provided for the first version of model and data analysis.

3. PIXEL's Models Definition

3.1. Environmental management model

3.1.1. Literature review

Environmental Management in ports in Europe usually consists of the application of an Environmental Plan. This Plan usually incorporates the following notions and elements:

- Aims for "compliance-plus".
- Aims to raise Environmental Awareness.
- Applicability of Environmental Monitoring.
- Involvement of community and Stakeholders.
- Follow the ESPO Code (European Sea Ports Organisation Environmental Code of Practice).
- Plan applied by Designated Personnel.

The ESPO codes (2003) constitute a significant tool for Ports Environmental Management.

As described in ESPO publication (http://www.espo.be) the Code presents an overview of environmental legislation as well as its effects on ports. They also make several important recommendations to port administrations to manage the implementation of EU legislation in accordance with the principles highlighted in the "Environmental Policy Code". It does not include mandatory requirements. EU legislation is implemented in different ways at the national and local levels; responsibility for the implementation of environmental legislation and policy varies from port to port and from member state to member state. The Code provides practical guidelines to port administrations when developing their environmental policies. Finally, the code presents port environmental management tools, which can be used.

Another environmental initiative of the European port sector is the EcoPorts (https://www.ecoports.com). It was initiated by several proactive ports in 1997 and has been fully integrated into the European Sea Ports Organisation (ESPO) since 2011. The overarching principle of EcoPorts is to raise awareness on environmental protection through cooperation and sharing of knowledge between ports and improve environmental management.

Two interesting tools and methods supporting ports environmental management developed by EcoPorts are the following (https://www.ecoports.com):

- **Self-Diagnosis Method (SDM)**
  SDM is a concise checklist against which port managers can self-assess the environmental management programme of the port in relation to the performance of both the sector and international standards. SDM is a checklist that allows ports managers to identify and reflect on environmental risks in their port. Aggregated data provided by EcoPorts members are used to build and update the sector's benchmark of performance in environmental management.
- **Port Environmental Review System (PERS)**

Developed by ports themselves, PERS has firmly established its reputation as the only port sector specific environmental management standard. The Port Environmental Review System doesn't only incorporate the main general requirements of recognised environmental management standards (e.g. ISO 14001), but also considers the specificities of ports. PERS builds upon the policy recommendations of ESPO and gives ports clear objectives to aim for. Its implementation is independently reviewed by Lloyd's Register.

These tools will be examined amongst others regarding their usefulness in relation with PIXEL.

3.1.2. Port operation and activities impacts

The port operations may include the following as explain in the "Manual of Best Management Practices For Port Operations And Model Environmental Management System":

- Dry bulk storage & handling.
- Liquid bulk storage & transfer (loading/unloading).
- Non-bulk chemical storage & handling.
- Port cargo handling equipment & rail/truck operations powered by diesel engines.
- Vehicle & equipment fuelling.
- Port authority oversight of tenant activities through lease agreements.
- Management of hazardous and non-hazardous waste generated by port/tenant activities.
- General operations that can impact neighbouring areas: noise, light, odour, trash, dust.
- Building & grounds maintenance.

Note that cargoes may include: coal, asphalt, salt, cement, grain, steel, machinery, passenger/auto ferry service.

Port Activities can be divided into two basic categories as showed by Paipai (1999):

Development Activities – May be on land and at the land-water interface and concern construction works with the associated transfer stations for construction material and possibly demolition works a debris.

Operational Activities – They occur both at the land-water interface and on-land.

Although PIXEL concerns mainly the Operation Activities, the development activities are also considering briefly here for the completeness of the presentation.

Table 6: Port development activities (Paipai 1999)

	Potential Impacted Medium				
Port Development Activities	**Surface water quality**	**Groundwater quality**	**Aquatic Habitats**	**Air quality**	**Humans (health & interests)**
Dredging	+	+	+	+	+
Unconfined open-water disposal	+		+		
Disposal on land	+	+	+	+	+
Land reclamation			+	+	+
Construction of waterside structures	+	+	+		+
Establishing of new buildings/structures on land	+	+	+	+	+

Table 7: Port operational activities

Operational Port Activity	Water	Air	Sediment	Soil	Habitats	Humans (health & interests)
	Potential Impacted Medium					
1. Cargo Handling and storage						
Dry bulk - organic	+	+	+	+	+	+
Dry bulk - ores and minerals	+	+	+	+	+	+
Liguid bulk - organic	+	+	+		+	+
Liquid bulk - minerals	+	+	+		+	+
Timber	+				+	+
Refrigerated goods	+	+				
Fish landing and processing	+	+				+
2. Workshop and yard activities						
Vehicle and equipment maintenance (including painting and stripping)	+	+		+		+
Vehicle and equipment washing	+			+		
Handling and storage of chemicals (non-bulk)	+	+		+		+
3. Ship breaking	+	+			+	+
4. Vessel and equipment repair and maintenance (including stripping and painting)	+	+				
5. Fuelling and bunkering (on-land & at land-water interface)	+			+		
6. Building and open area maintenance	+			+		
7. Vehicles storage and transport in car terminals	+					
8. Ship and shore solid waste collection	+	+		+	+	+
9. Public access/areas and recreation in harbour waters and shore	+		+		+	
10. Shipping						
Ship movement		+				+
Ship discharge - ballast water	+		+		+	
Ship discharge - sewage	+		+			+
Ship discharge - bilge water	+				+	+
11. Transhipment						
Containers						+
Ro-Ro						+

Passenger/Ferry						+
12. Maintenance dredging and disposal	+		+	+	+	+

As previously mentioned, supply chain modelling is a necessary step to correctly identify sources of emissions and predicting the impacts of cargo transitions on energy costs, overloading of the transportation system, etc. In order to better model the different supply chains, work is underway on this subject with the ports. For example, the data below comes from the first work in progress on the port of Monfalcone. Same type of work will be done with other ports.

Table 8: Port of Monfalcone – Cargo handling supply chain (main goods handled in portorosega berth)

CARGO TYPE	**SC #**	**Frequency**	**MACHINES SEQUENCE (from ship to deposit)**	**DISCHARGE RATES**
Caolin	1.1	97%	Mobile Crane>Hopper>Truck	700 - 1,000 tons/working squad/workshift
	1.2	3%	Mobile Crane>Truck	700 - 1,000 tons/working squad/workshift
Cellulose	2.1	100%	Mobile crane>>MAFI (Tractor + rolltrailer)>>Forklift	2,000 – 2,500 tons/working squad/workshift
Slabs	2.2	100%	Mobile crane>>MAFI (Tractor + rolltrailer)>>Forklift	2,500 – 3,000 tons/working squad/workshift
Wire rods	2.3	100%	Mobile crane>>MAFI (Tractor + rolltrailer)>>Forklift	1,000 – 1,200 tons/working squad/workshift
Hot Briquetted Iron	3	100%	Mobile crane>>Dump truck>>Skid steer loader	1,000 – 1,500 tons/working squad/workshift
Pig Iron		100%	Mobile crane>>Dump truck>>Skid steer loader	1,400 – 1,500 tons/working squad/workshift
Cars	4	100%	Car	150 - 180 units/working squad/hour
				*working squad = 8 - 15 units depends on goods type, whille for RORO 27 units are usually used *workshift = 6 hours
MACHINE TYPE	**Fuel type**	**Power**	**Energy Cons. (average)**	**Models**

Mobile Crane	Diesel	313 - 768 Kw(630 Kw HMC280E; 597 Kw HMC260E; 768 Kw HMC300E; 313kw Sennebogen)	18 - 60 l/h (39/h HMC2820E; 29/h HMC260E; 35/h HMC300E; 29l/h LMH 550; 18 l/h Sennebogen; 60 l/h MHC 4000)	Gottwald HMK 280E, 260E, 300E - Reggiane Cranes MHC 4000 MHC 130 MHC 200 - Liebherr LHM 550 - Sennebogen 750 KW
Hopper	Diesel	-		Prototypes (Ardea S.r.l. - DEAL S.r.l., Ortolan)
Truck	Diesel	320 Kw	3 km/l	Iveco stralis at440
MAFI (Tractor + rolltrailer)	Diesel	164 Kw	5,5 l/h	Terberg YT222
Forklift	Diesel	43 - 147 Kw (147 Kw Svetruck 16 120-38; 58,7 Kw Hyster H5; 43 Kw Hyster H3)	8 l/h	Svetruck 16 120-38 - Hyster H5, H3
Dump truck	Diesel	332 kw	-	magyrus a440st-e4
Skid steer loader	Diesel	53 kw	5 l/h	Caterpillar 242
Car	Diesel/Gasoline	-	-	Renault, Dacia, Lada, Fiat, Mercedes, BMW…

3.1.3. State of the art approach

As it can be seen in the above table by the variety of impacted mediums by the port's operation, Ports Environmental Impacts should be better addressed by developing a model of environmental management. This model should integrate partial models like energy model, pollution and transport demand models as well.

The need for interoperability of those models is well depicted in the Figure 14 concerning emissions (pollution) modelling.

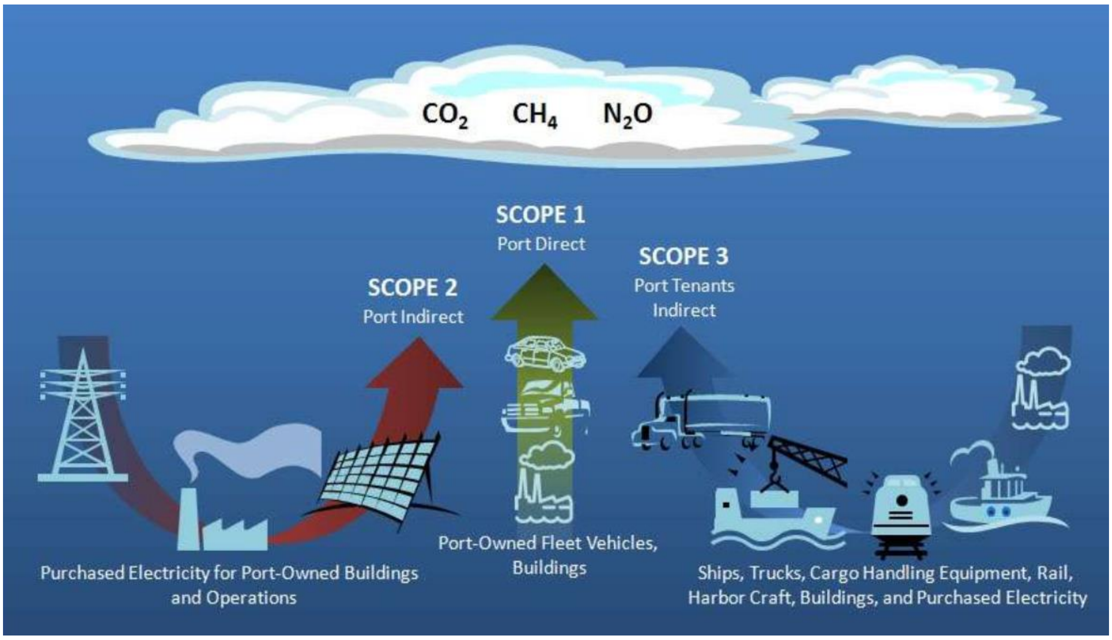


Figure 11: Scope of a port environmental management model (The Port of Los Angeles, 2012)

Moreover, emissions modelling is strongly related to environmental monitoring data. An interesting review of Environmental Monitoring Aspects in Ports is presented in the "Mediterranean Environmental Review Monitoring for port Authorities through Integrated Development[3]" Project as follows:

- **Air Quality** – Via air quality stations to monitor concentrations of various parameters (e.g. PM_{10}, NOx, CO, SO_2, BTEX). The data collection should be in continuously logged (24hr measurements).
- **Noise** – Sound meters strategically placed in order to receive data and feed propagation models either regularly or continuously.
- **Water quality** – Sampling analysis of water and sediments using various parameters such as BOD, COD, E. coli, pH, salinity, TDS, heavy metals etc
- **Biodiversity** – Conducting inventories of habitats and species.
- **Waste management** – Under this category there are various waste streams to be monitored. Ships waste, recyclable waste from offices and terminals, third party waste, ships sewage, ballast water, etc.
- **Energy consumption** – Monitoring energy consumption can be used as a method of evaluating energy efficiency of the system.

3.1.4. Good practices

Many ports have already applied Environmental Management Systems with positive results for the environment. So, there is several good practices implemented by various major ports worldwide. Such is, amongst others, the case of Los Angeles port.

The Port of Los Angeles initiated a pilot Environmental Management System (EMS) in 2003 and obtained the ISO 14001 certification. Most recently, the program was recertified under the updated 2015 Standard, indicating the ongoing commitment of Port management and staff to continuous environmental improvement (https://www.portoflosangeles.org).

According to the aforementioned website, the Los Angeles port EMS has been an overwhelming success. Since implementing the EMS, employees are engaged with the system on a daily basis, creating a sense of ownership and accountability. This engagement in the EMS has resulted in:

- Reduced disposal of overall hazardous waste.
- Recycling of most of the paint waste.
- Reduced bilge water shipped off as hazardous waste.
- Implementation of a wood waste recycling program.
- Improvement of emergency response capability.
- Increased assurance of regulatory compliance.
- A clear process to manage increasing risk and complexities of environmental management.
- Continued development of tools and systems to help track and reduce our carbon footprint.
- Strengthened inter-division communication.

The EMS has also resulted in important and significant cost savings through:

- Reduction of hazardous waste, resulting in an estimated savings of over $100,000 per year.
- Eliminating the need for additional Title V air requirements.
- Salvaging and replacing non-compliant equipment.
- Reducing purchase of air emission credits.

[3] http://medmaritimeprojects.eu.dev10.tildecms.com/section/mermaid

In our approach during next phases of PIXEL these good practices will be thoroughly considered. We will try to get ideas from various success stories in environmental port management and then try to succeed similar or better results with the aid of PIXEL tools.

3.1.5. Methodologies

Methodologies to be used in the Environmental Management Model which will be developed in this project will be thoroughly examined in the next steps.

Methodologies used in Green Ports assignments are presented by (Bucak 2016). As stated in this citation, ports must carry out green performance criteria to be mentioned green port. Although it is differential by prescriptive organization to organization, thirty-two green performance criteria were collected. These were gathered under five group as follows: air pollution management, liquid pollution management, solid waste and the other pollutants management, aesthetic and noise control management, and marine biology preservation. The methodologies reported in this citation included the following:

- The marketing of urban regeneration and green washing literatures have been linked via case study of the Port Adelaide revitalization.
- Probit Analysis Program has been used in order to determine toxicity of sediments received as sample from 7 Spanish city ports.
- A simulation model has been used to determine the optimum number of container handling equipment to increase the lean capabilities of a Turkish port. Arena 12.0 Simulation Software has been used.
- Two Greek ports were examined as case studies investigating the integration and adaptation of the environmental legislation, national, international and European.
- Integer Linear Programming (ILP) model and heuristics has been proposed to determine optimum port-cost and power-consumption.
- Green Port Fees and Marginal Costs have been evaluated in one table.
- Calculation related to ship emissions.
- A method which is composed of financial accounts (MC3) is used to estimate the Carbon Footprint of a port.
- A static game model was developed under the asymmetric circumstance to research cooperative relations of low-carbon green oil port between the oil port enterprises and other enterprises and achieved good research achievements.

Even though these methodologies will not be used in PIXEL, useful ideas may be derived from some of them.

Because of the complexities to be encountered in a port environment (inputs of models should include labourers, equipment, hydrographical attributes, information and communication technology, volume of traffic handled, number of port personnel trained, cargos served etc), one methodology that might be examined is the Data Envelopment Analysis (DEA) (Haralambides, 2015).

However, the most difficult issue to address is the interoperability of the partial models. Modern notions, algorithms and technics need to be examined, amongst others literature include the following:

- Resource management.
- Big data application.
- Data aggregation.
- Sensor connectivity to the Internet and the cloud.
- Novel communications solutions.
- Networking and IoT Technologies, etc.

3.1.6. Scenario manager definition and interoperability of PIXEL's models

The works for clearly defining what is a scenario manager is an ongoing work that still need to be improved. This will be described in the second version of the deliverable (D4.2). However, some firsts insights could be found in (Tzannatos 2010).

The development of the interoperability of energy demand and production models, pollution and transport demand models will also be addressed in the second version of this deliverable (D4.2). A deep work will be done in order to clearly link the inputs and the outputs of each model in order to develop a modelling and simulation methodology taking into account the impact of the results of one model on another.

3.2. Energy demand models

For operational actors in ports, energy efficiency is an important issue, both from environmental and economic perspectives.

In time, ports would like to be able to optimize their energy flows. In order to do so, a prerequisite is to manage and to quantify energy consumption and production in the context of complex industrial processes. This PIXEL tool focus on enabling such quantification for small and medium ports. More precisely, in response to modelling needs expressed by consortium ports, we will focus on the following three complementary elements:

1. Energy consumption (fossils and electric) associated to the cargo transition across port.
2. Electricity produced by local source as photovoltaic panels.
3. Balance between electricity consumption and production.

The tool can be considered as a three-sided prism, where each of those elements constitutes a facet. In the following section we describe the three corresponding modules.

3.2.1. Energies consumption module

3.2.1.1. Context

3.2.1.1.1. Addressed issue

Purpose

This first module aims to enable ports to calculate their energy consumption relating to their activities. This means that for a specified cargo, after its supply chain modelling (see previous section), the module will estimate the corresponding energy consumption across time. This enables a predictive estimation if the port activities scenario is a forecast (e.g. maximum net electricity consumption during next week). It can also test hypothesis by comparison among several port activities scenario (e.g. energy saved by supply chain modification).

Constraints

Ports and technical partners' analysis have led to a list of some essential constraints and needs that we should consider when designing the module:

- Deployable by different ports (addressing different types of goods in different ways).
- Sustainable in time despite port's evolutions (e.g. machines or goods typology change)[4].
- Easy to appropriate for PIXEL end users (i.e. port's operators).
- Code easy to maintain for future developers (as an open source project).
- Explainability of calculation results (limit the blackbox effect).
- Relevant in different contexts (e.g. daily management / investment strategy etc).
- Synergize with others PIXEL tools.

[4] If necessary, the parameters requiring an update must be explicit

Some other elements could be listed as technical constraints, such as (i) expected precision and accuracy of results, (ii) model's call frequency and (iii) computational time. For now, these elements are still unknown.

Scope

The total port's activities consumption is the sum of all listed elements in Table 9. However, we will use an incremental approach, with a gradual widening of the scope. We will begin with the clients' priority element, the port supply chains machines. Later, other elements can be included on the same model canvas

Table 9: Energies consumption module's scope

Handling	Support	Transport
Port's supply chains machines	Lighting	Boats (maritime and fluvial)
Multimodal platform supply chains machines	Buildings	Trucks
	Berth power supply	Trains

Market solutions limitations

In a general point of view, the solutions for energy optimization in an industrial context consist of a data acquisition component "Supervisory Control and Data Acquisition" (SCADA, which includes a hardware layer of sensors) and an information processing component, Electrical Power Management Systems (EPMS, mainly a software layer related to process monitoring).

For industries with high energy flow control needs, equipment manufacturer can offer integrated solutions (Siemens 2017). When needs are more focused on monitoring, consulting firms can assist industrialists in setting up a global plan for energy management[5]. Finally, when focusing on energies tracking and reporting, on and off-line software can be acquired[6].

Even though big ports can set up ambitious projects[7], three points make those market solutions less suitable for small and medium ports. Firstly, some ports wish to make prediction about the energy consumption. This feature is not so common, especially in the context of prediction for different port's activity scenarios. Secondly, those solutions require a global plan for deploying consumption sensor and data acquisition instruments. This point is discussed thereafter. Thirdly, a significant obstacle may be the lack of in-house expertise dedicated to evaluating, deploying, or maintaining such solutions.

3.2.1.1.2. Available data

Energies consumption data

For energy data, a major issue is there is lack of sensor. For electrical consumption, some sensors exist, as those deployed for SCADA infrastructure. But beside cost issues, another obstacle is the machine ownership. Indeed, for some ports the terminals activities are delegated to operators. They have no direct constraints to feed Pixel with data, but it seems they do not want it. It is then difficult to deploy sensors on their premises. Thus, other strategies must be investigated to get energy consumption data.

[5] Examples: Affinity Energy, Ecopare and others.
[6] Examples: Entronix EMP, Energy Elephant and others.
[7] Examples: Rotterdam's Deltaplan Energy Infrastructure plan, Stockholm's Environmental Strategist and others

Nature

Two distinct types of data related to the energy consumption can be distinguished. First, the total energy brought into the ports during a certain amount of time (i.e. bought to an external energy provider). Second, the energy consumed by a unit operation (e.g. the electrical energy consumed by a pump for one hour).

Access / provider

Access to the total energy brought to the port could be done through the corresponding bills. This may require some investigation about terminal operator's willingness to share those data and legal constraints. But that seems to be reasonably common and an easily accessible data source. It would be quite easy to convert such data to a standard table format in order to feed energy models. If this possibility is validated, more specifications about such data conversion will be defined in D4.1 v2.

In this regard, an important remark must be made about representativeness of GPMB use-case. This port has the particularity of being an electricity supplier both for terminals operators and other industrial players located on the port basin. As such, it can access the electricity consumption that it charges to its customers in real-time.

For data relative to unit operation consumption, several estimation approaches are listed by (Muller 2016):

- Usage of information of technical datasheets.
- Life cycle analysis-based methods.
- Mathematical-physical methods.
- Empirical methods.

In our case, two solutions are considered. The first one is to list terminal supply chain machines, and for each one gets the technical specifications concerning machine nominal consumption. The second one is to use data from literature, as done by (Serno 20016) and pointed in Table 10.

Table 10: Collecting energies consumption data from literature (from Serno2016

Component	Sub-component	Bibliographic reference
Material flow components	Storage and retrieval machine	Siegel et al. [18]
	Forklift	Müller, Krones and Hopf [13]
	Roller conveyor	Günthner and Habenicht [4]
	Depalletizing robot	KUKA reference value [34]
	Logistics workplace	Kramer reference values [5]
	Trugger train	Müller, Krones and Hopf [13
Building technology		Günthner et al. [8]
Transport logistics		DIN EN 16258 [45]

Historical / sample

For total incoming electricity, GPMB has a historical data-set. Monthly total electrical consumption for Bassens site has been recorded from January 2014 to April 2017 (i.e. 40 values available). From this sample, one can see that a seasonal trend seems to appear with higher electrical consumption during winter (see Figure 15). But no thorough statistical study can be conducted without more data. Indeed, if this seasonal effect is real, it is not clear if its due to (i) support consumption seasonality (i.e. higher needs for lighting and building during winter) or to (ii) cargo typology seasonality (i.e. type & volume).

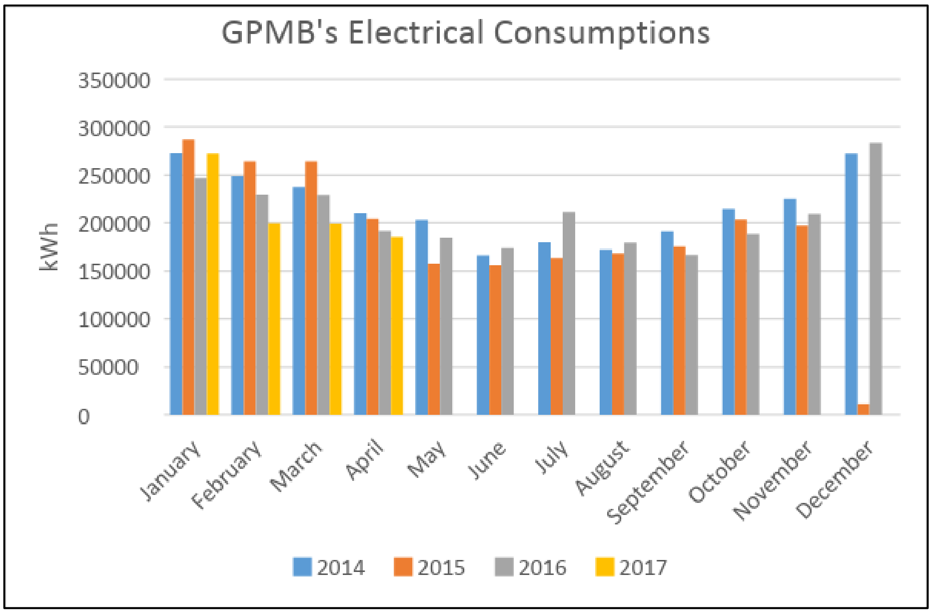


Figure 12: Bassens (GPMB's site) monthly total electrical consumption from 2014 to 2017

GPMB has deployed 13 real-time electrical consumption sensors into the port. During the PIXEL project, GPMB plans to collect those data with a time step of 10 min and store them inside a dedicated database. Such data-set can be valuable for energy consumption modelling, as it can be used for both statistical analysis and models' validation.

Meteorological data

As pointed above, meteorological conditions can impact energy consumption. Firstly by modifying port's activity. As an example, there is no cereals handling during rainy days. Secondly by impacting the energy required for an identical activity. As an example, wind can increase crane energy consumption. Thirdly by modifying energy spent on support. As an example, in winter there is an increased energy requirement for berths' illumination and heating building. Thus, meteorological data may be required to improve the port energy consumption model.

Sources

Those data are measurement time series relative of temperature, precipitation, sunshine, wind direction and wind speed.

Access / provider

Such data can be quite easily acquired through a weather station or buy.

Historical / sample

Due to the easiness to get such data, historical data set should be quite easy to obtain.

3.2.1.2. State of the art

Globally, models that can predict energy consumption are divided into two types of approach, on the one hand the "statistical models", on the other hand the "mechanistic models".

Statistical models typically fall within the analysis of time series, multifactorial regression or neuron networks (for a general introduction to Machine Learning approaches for energies consumptions, see (Fallah 2018)'s review). The underlying mechanics is to extract patterns from energy consumption historical data-set (and possibly contextual variables), in order to infer future consumption.

Despite their great qualities and usefulness, statistical models do not seem to be appropriate for constituting the core of the consumption module given the constraints identified. First, because no historical data-set is available for model initialisation, which is required even for a reinforcement learning algorithm.

Second, in the context of a significant evolution of port activities (evolution of equipment, traffic or other), the accuracy output of the model is likely to collapse. To prevent that, expertise about statistical model deployment, control and update would be required in port's staff. But this is in contradiction with the specified constraints to easily deploy the PIXEL platform in small and medium ports and allow operators to appropriate it.

Mechanical models are based on deterministic analysis of the physical characteristics of the system in operation. Knowing the mechanisms involved during the modelled process, a deterministic calculation can predict consumption.

The approach could be similar to the one proposed by (Serno 2016). At each transition of goods within the port, a list of handling operations is associated. Each of these operations points to a machine for which characteristics are known. Knowing the machine nominal consumption and throughput, as well as the cargo volume, we can estimate operation energy cost. By integrating across time, the consumption of all the operations related to the cargoes transition in port, we obtain the total consumption as a time series.

Given the constraints identified, such an approach seems to be more appropriate for energy consumption modelling than a statistical approach. First because there is no mismatch with listed constraints.

Second because this approach is based on describing daily activities that port's operators know well. This may facilitate PIXEL employment by its end users.

As pointed in the previous sections, we currently focus on energy consumptions due to cargoes handling for transit into ports. For support consumptions forecasting (e.g. building and light), it may be more relevant to use a separate model. Academic reviews as (Li 2015) provide comparison of several models dedicated to buildings' consumption, as BREDEM (British), PRISH & HBM (United States), CHREM & CREE (Canadian), NKFM (Finland) and HM (Belgium). The second phase of the study should point relevant information to enable us to choose a convenient model. As an example, knowing the most common use about turn on the berths' lights (automatic with fixed hour, brightness detection or manual).

3.2.1.3. Working hypothesis

3.2.1.3.1. Model Description

For each cargo whose transit inside port will be modelled, a corresponding sequence of machine operation is provided as input.

For each operation, both the duration and the machine nominal consumption are known. The product of those two pieces of data gives the operation's energy cost.

The total energy required for the port's activities scenario is then calculated by adding times all operations' (energy) cost.

3.2.1.3.2. Inputs

Port's Activities Scenario

This input is introduced in section 2.3.1.2 and described in section 3.1.6. This can be seen as an oriented graph (probably provided as a JSON) containing:

- Scenario's information (such as identification number and generation timestamp, probably as a header)
- Cargo's information (such as identification number, category, amount)
- Supply chain's information (such as ordered machine identification number sequence[8], duration and fixed beginning or ending time stamp)

Weather conditions

For buildings' consumptions, the temperature would probably be required (expressed in degrees Celsius) as an input. For inputs relatives to lightning's consumption, several possibilities exist, due to the versatility of ports lightning management. Environmental inputs such as temperature usage will be reported in D4.2.

3.2.1.3.3. Parameters

Machines' specifications

This parameter is described in section 2.3.1.3.

Buildings' and lights' specifications

Even if the sub-model is still unclear, the corresponding parameters would probably include buildings' information such as areas (m²), heating systems, energies class scores (e.g. the French DPE) and for lights, numbers, and technologies (sodium, LED).

3.2.1.3.4. Outputs

The model outputs will be an energy consumption list (one record for each consumption item). If a timestamp is provided for every port's activities scenario operation, this temporal information will also be provided in the output. This output can be delivered as file with a JSON-like structure that can be similar to:

- Metadata:
    - Corresponding port's activities scenario
    - Call's status (done/error#)
    - Call/input's reception timestamp, output emission's timestamp, calculation's duration
    - Input values
- Consumptions list:
    - Step 1:
        - Machine #: Energy type, Consumption, begin, end
        - …
    - …
- Summary:
    - Warning (e.g. list of machines with no corresponding nominal consumption and thus not considered for calculation)
    - Total electricity consumption time series

[8] With a convenient syntax to properly express sequence

- Total fossil fuel consumption time series[9]

3.2.1.3.5. Limitations and assumptions

The main concern is about receiving all inputs and parameters, and with adequate granularity and exactitude. Obviously, the model will provide erroneous output if:

- some operations are omitted inside the scenario provided as an input[10],
- a listed machine does not have its corresponding nominal consumption.

But other limitations must be underlined. There is a trade-off between model's simplicity and output's precision. As model simplicity is a goal, the energy consumption will be limited to an average estimation. First, because the nominal consumptions are average values. This means that several elements relative to the machine operation are not explicitly considered but averaged. Some examples: difference in engine consumption cold / hot, brings up / down a charge, horizontal transport load / empty etc. Second, because contextual elements are not considered. But many factors can impact operator and machine efficiency and thus the energy consumption. As an example, temperature can substantially modify the viscosity of a fluid and therefore pumps' efficiency. Or two distinct machines drivers may have different efficiency.

However, with the same model structure, a later more sophisticated version could take into account such elements and refine the modelled consumptions.

3.2.2. Electricity production module

3.2.2.1. Context

3.2.2.1.1. Addressed issue

This module's aim is to predict the electrical energy that will be produced by a given photovoltaic power plant. This can be done for two extreme use scenarios.

A first use scenario is to size a photovoltaic power plant construction project. Typically, the total annual production is expected, eventually discretized to monthly average values. This correspond to average estimation considering average weathers conditions. In this context the model may be a "what if?" tool, which provides explainable average estimation from a set of installation's characteristics as inputs.

A second use scenario is to pilot a power grid considering the incoming electrical production. This correspond to continuously predicting next minutes or days production. In this context, the user does not have control on weather and photovoltaic power plant's characteristics are fixe. Then there is no need for a "What if?" approach or result explainability, but high accuracy and a suitable calculation time are required.

Between these two extreme cases exists a range of intermediate situations. To determine both the precise future use and the available data[11] is crucial to select the optimal modelling approaches. The present section aims to expose key considerations and what seems currently the most probable approach for this module.

[9] This may split on several fuel categories
[10] In such case, model will not be able to trigger a warning
[11] Note that available data can depend of ability to buy those data. Thus another key point for choosing the optimal model may also be financial investment strategy.

3.2.2.1.2. Available data

Photovoltaic panels' specifications

Nature

As a relatively mature field, photovoltaic power plants can use different panels technologies (thin films, mono or multi crystalline silicon, CIS or CdTe, with or without anti-reflextive coating…). Beside technical considerations as weight, maximum power voltage and other, each panel technology have specific characteristics that impact modelling. For his module, the most relevant data are panels' efficiency (similar to a conversion rate) and thermal drift.

Access / provider

For known photovoltaic panels, those data are provided by manufacturer. For a general estimation, standard values are provided in **Erreur ! Source du renvoi introuvable.**.

Table 11:Standard assumption for different module types (from NREL, SAM manual)

Module type	Cover type	Efficiency	Temperature
Standard	Glass	15 %	-0.47 %/°C
Premium	Anti-reflective	19 %	-0.35 %/°C
Thin film	Glass	10 %	-0.20 %/°C

Installation's setup

Nature

Several setups can be used for photovoltaic power plants. Those photovoltaic panels deployment conditions are key parameters for production. Such information is size (number of panels), site localization (longitude & latitude), use terrain's horizon (neighbourhood's shadows), base (fixe or 1D/2D tracking system). The setup result from several constraints that can be technical (especially the weight if installed on a roof), legal or budgetary (investment cost and amortization scenario).

Access / provider

As the arbitration is made by the (future) owner, he provides those data.

Irradiance

Nature

Photostatic panels convert energy from the sun electromagnetic radiation to an electrical energy. The irradiance is a measurement of the incoming energetic radiant flux, expressed as W/m². Depending on the irradiance origin and measurement, it may require a correction (eg. for satellite-based solar radiation data).

Access / provider

For direct and real time measurements on site, sensors are available[12]. Past and average values can also be obtained through open-data portal (see Climate Monitoring Satellite Application Facility CMSAF[13] or National

[12] http://reuniwatt.com/en/solar-incell-reference-cell-weather-station/
[13] https://www.cmsaf.eu/EN/Home/home_node.html

Solar Radiation Database NSRD[14]). This can be used for future irradiance estimation based on average values. Such feature is frequently embedded in tools as PHotovoltaic Geographical Information System (PVGIS) or System Advisor Model (SAM) (see section 3.2.2.2.2).

For predictive irradiance estimation (non-based on past measurements), another approached can be to model irradiance from calendar and weather condition (particularly cloud cover, see Sung 2015). Such irradiance prediction can also be bought to external services (see section 3.2.2.2.2)

Historical / sample

CMSAF provide reliable irradiance historical data-set for European sites.

Weather data

Nature

This data category includes temperature, wind direction & speed, humidity, rainfall and sunlight duration.

Access / provider

Those data can be measured with sensor (real-time data and local historical data-base creation, typically with a connected weather station), obtained from open-data portal (historical data) or as a service (predictive measurements).

Historical / sample

Obtain historical data should not be a serious difficulty.

Electrical production

Nature

For a running photovoltaic power plant, effective electrical production is measured and a historical data-set can be obtained. For a statistical modelling approach, this is a key component.

Access / provider

The photovoltaic power plant’s owner can provide live and historical data.

Historical / sample

As there is currently no running photovoltaic power plant on use case site, there is no historical data-set, which is a strong constraint.

3.2.2.2. State of the art

3.2.2.2.1. Literature review

Direct and indirect approaches

There are two main approaches for photovoltaic power plant production’s prediction (see **Erreur ! Source du renvoi introuvable.**).

[14] https://nsrdb.nrel.gov/

The indirect approach uses an irradiance value, injected as an input for electrical production prediction. The irradiance can be predicted through weather data, satellite image, sky image analysis (cloud tracking). It can also be supposed similar to the average of recorded values for similar period and site. The irradiance value is then injected as an input for the second stage of the calculation, that can be a mechanical model or a statistical model (if an electrical production's historical dataset is available).

If a mechanical model is expected, some contextual information may have to be consider for choosing the optimal model. As an example, the Sandia model is a well-known mechanical model (Kratochvil 2004), but it does not natively take into account the degradation or seasonal fluctuation factor. As pointed by Pierro 2017, this is not an issue if the panels are of crystallin's technology, but it can lead to significant decreasing prediction performance with time if the panels are thin films. In such case, some corrective factors have to be introduced, as it is done in the SAM tool.

The direct approach does not rely on an explicit irradiance calculation. Instead, a statistical model predicted electrical production based on the photovoltaic power plant production's historical dataset and contextual data. There is a wide range of statistical models, from simple persistent model to complexes hybrid neuronal network. Each of those models have strong points and weakness (see Das 2018 extensive review with pertinent consideration to available data and forecast horizon). Note that simple models based on persistence assumption are commonly used as control models (see **Erreur ! Source du renvoi introuvable.**). They can require a limited amount historical data-set, while they may allow acceptable accuracy (Bossavy 2013).

Finally, some hybrid approach can be done. As an example, a more accurate prediction can be achieved by using a correction factor to the mechanical model's output. This correction factor is predicted by a statistical model based on an historical data-set of observed mechanical model's predictions errors (Gao 2016).

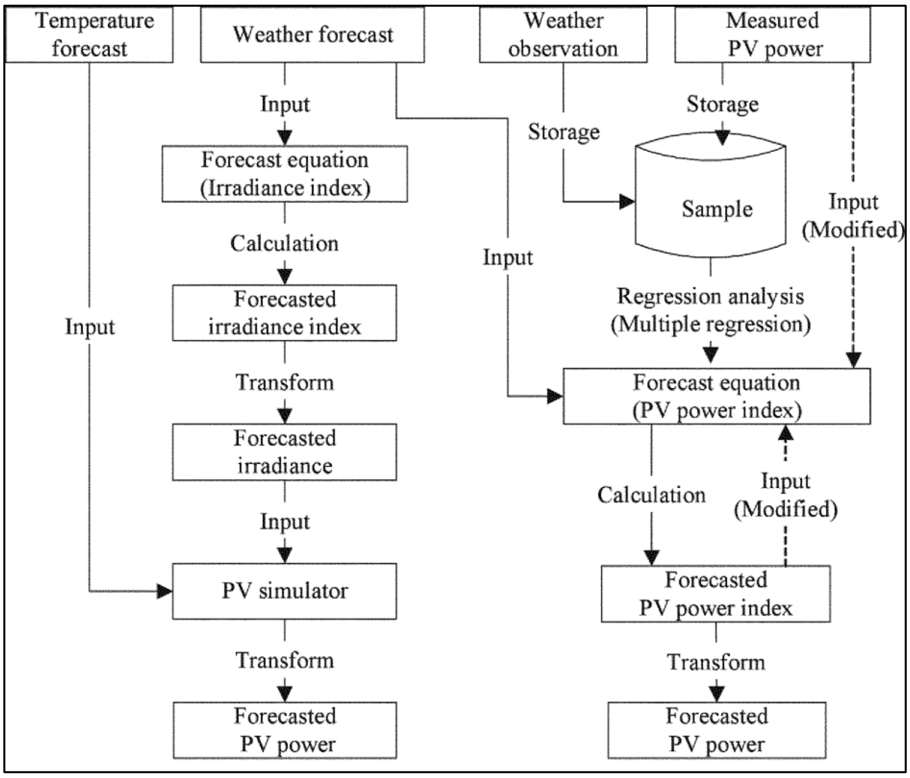


Figure 13: Indirect (left part) and direct (right part) approaches side by side illustration (from Kudo2009)

Prediction's performances

Several studies compare both approaches. Even if several comparative studies (Pierro 2017, Kudo 2009) and reviews (Das 2008) point a better prediction for direct models, both approaches share comparable range of precision.

To provide some guidance, about 15% root-mean-square error (RMSE) compared to actual electricity production can be expected. But this is a rough estimation, and the actual prediction error can vary significantly from about 4% (Wang 2017) to 30 % RMSE (Kudo2009) depending of both models (see Figure 17 from Pierro 2017) and context. In this regard, the forecast's horizon (see Bocquet 2016) and the weather data-set quality (as pointed by Kudo 2009) have a strong impact on model's prediction accuracy.

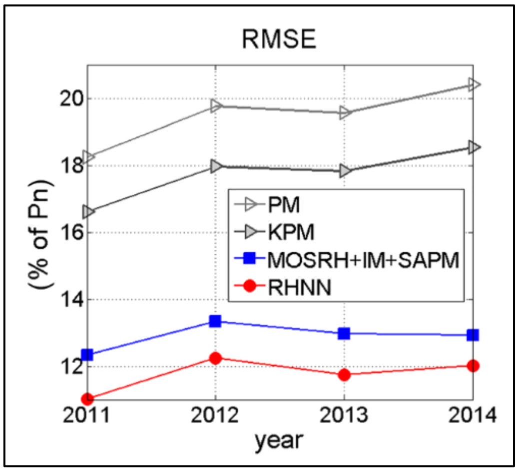


Figure 14: Direct (red) and indirect (blue) performances comparison (from Pierro2017)

3.2.2.2.2. Existing tools and software

A broad variety of solutions exist on the market, from advanced simulation software[15], to irradiance short term forecast online services[16]. But from the currently available information, the most suitable models/tools for this module seem to be PVSIG[17] (from JRE) or SAM[18] (from NREL). Indeed, those tools based on indirect mechanical models:

- Are easy to use even for non-simulation/modeling/photovoltaic specialists.
- Allows several setup configurations (solar tracking, batteries, on & off grid connection).
- Provide easy to use and up to date panel's technologies specifications (crystalline, thin film etc).
- Provide irradiance data-base (for typical year prediction) with fine temporal resolution (up to hours).
- Provide optimal orientation recommendations for fixed panels.
- Can take neighborhood shadows into consideration.
- Have extensive documentation (from tutorials to technical reports and scientific papers).

Beside those common features, one can note that:

[15]Examples: TRNSYSM: http://www.trnsys.com/, HOMER: https://www.homerenergy.com/
[16]Examples: http://steady-sun.com/, https://solargis.com, https://solarwebservices.ch/
[17] http://re.jrc.ec.europa.eu/pvgis.html
[18] PVWatts is an online module for basic calculation https://pvwatts.nrel.gov/index.php whereas SAM is the complete solution https://sam.nrel.gov/

- PVGIS allows calls thought API while SAM is an executable software (with available Software Development Kit (SDK)). PVGIS is based on indirect mechanical model, allows easy photovoltaic production prediction for several setup configuration.
- As both are related to the National Renewable Energy Laboratory (NREL), SAM is natively linked to the National Solar Radiation Database (NSRD), limited to USA records. But the European Joint Research Centre (JRC) and RNEL have already started sharing data, and importing European irradiance historical record into SAM should be possible.
- SAM provide advanced modules, from technical features (e.g. multiple simulation runs for parametric and sensitivity studies) to financial features (e.g. calculates depreciation period, cost considerations and economic incentives). SAM allows photovoltaic production prediction, and other annexe module for power plant sizing and piloting.

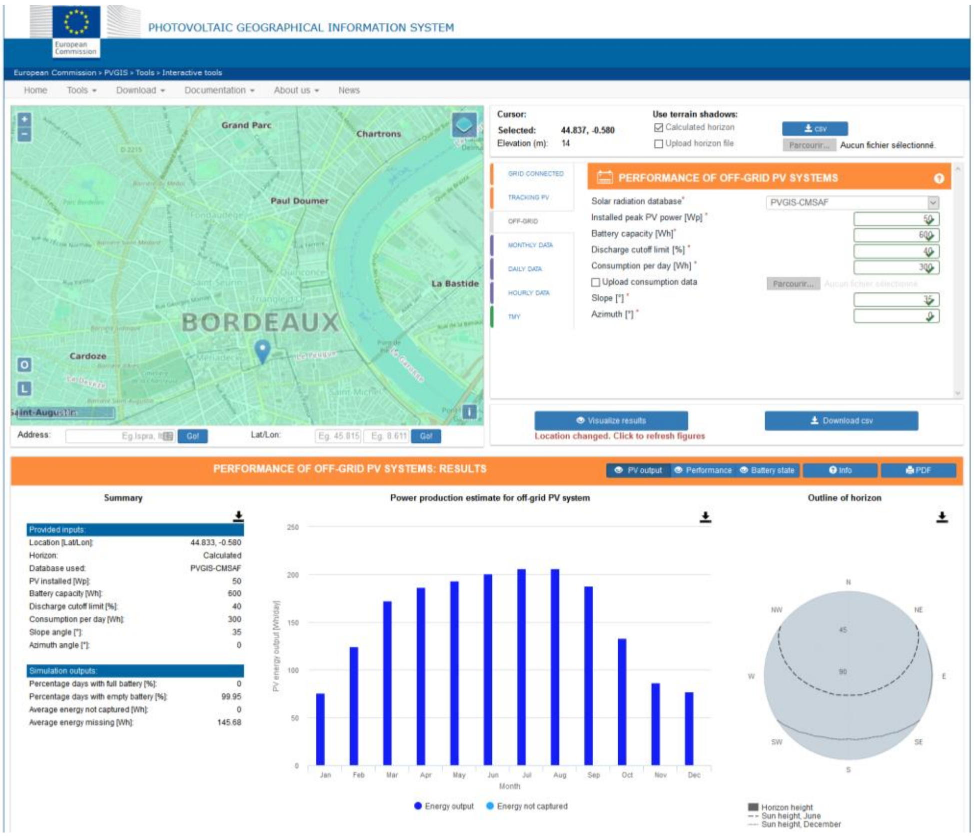


Figure 15. PhotoVoltaic Geographical Information System screenshot

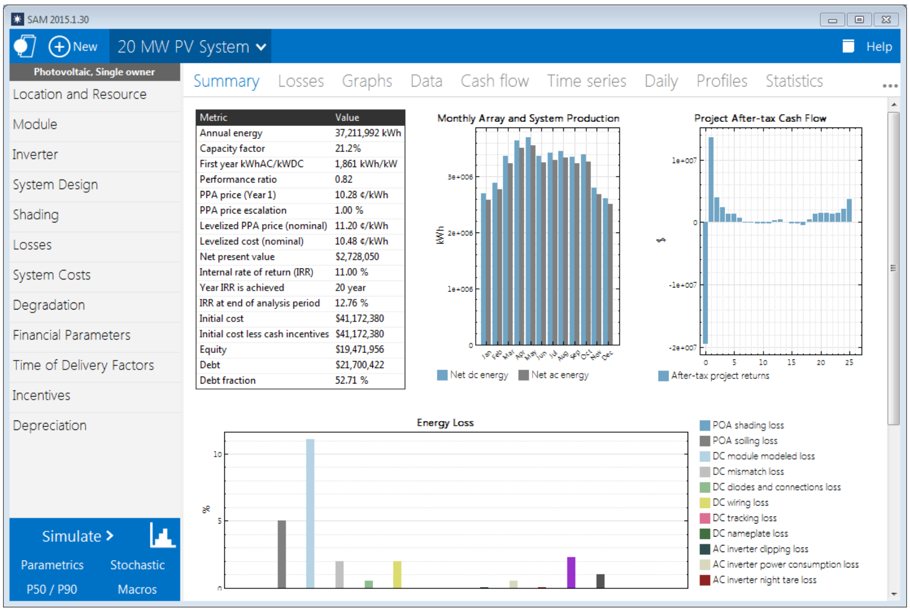


Figure 16. System Advisor Model (SAM) screenshot.

3.2.2.3. Working hypothesis

3.2.2.3.1. Model Description

As there is no existing photovoltaic power plant electrical production historical data-set, statistical approach cannot be developed currently. A mechanistic model will then be used. The most promising solution for this module seems to rely on PVSIG or SAM. As pointed above, those models provide most of the features required by ports. The choice between those two models will be made after tests with ports. PVSIG would be use though its API, whereas SAM would be an executable run locally.

3.2.2.3.2. Limitations and assumptions

Natively those tools use calculated "typical" irradiances as input data. That is, reconstituted values for each day of the year based on historical records. These values do not consider any weather forecast information available when used. So, for any user and at any time, the same value will be predicted for a site and a given moment. Thus, the model output precision relies on the fact that the average irradiances values used as input are representative of the actual irradiance occurring.

If this assumption brings inconvenient error on prediction, two actions can be undergone.

First, one can use irradiance forecast from any services as input data. Second, if an historical data-set is available, a dynamic correction factor can be applied on the model output. This correspond to adding a statistical model, as illustrated by (Gao2016).

3.2.2.3.3. Input data

The input data are irradiances temporal series, provided by online data-base.

3.2.2.3.4. Output data

The output is a photovoltaic power plant electricity production time series.

3.2.2.3.5. Model parameters

The parameters are site characteristics (longitude, latitude, shadows), photovoltaic panel setup (number, size, orientation or tracking system, DC/AC conversion ratio, consumption) and cells technologies.

Other parameters as connection to grid or batteries systems can be required (depending of the use).

For a complete description, see PVGIS user's manual[19] or SAM Photovoltaic Model Technical Reference[20]

3.2.3. Energy balance module

3.2.3.1. Context

From difference between electrical consumption and production, the grid load can be calculated. Knowing this balance enable operators to adjust port's activities and improve information sharing with other actors.

For examples, it can be used to trigger a predictive alert when the net consumption will reach its annual peak. This annual peak is an important element for energy subscription price calculation. Thus, operators may choose to delay the most consuming operations to avoid this peak. By doing so, electrical net consumption can be spread on few days, and the electricity subscription price can be reduced every year.

Another example is to predict an electricity over-production that will be sent to an external grid. The owner has to inform the grid operator (typically 24h in advance) about the amount of excess electricity that will be sent.

3.2.3.2. State of the art

Electrical grid load can be indirectly forecast by the difference between forecasted consumption and forecasted prediction. This is the most common situation, and this feature is commonly integrated in energy monitoring tools, as SAM for example.

One can note that in some context, the grid load can also be directly forecast, without previous consumption and production forecast. Indeed, as production and consumption predictions can show high variability, indirect forecast may stack error from both. Thus, some authors propose to make a direct grid load prediction. This corresponds to a statistical model using historical data-set about net consumption and contextual information (as weather for example). They argue a lower error by removing previous prediction error accumulation (Abedinia 2016).

3.2.3.3. Working hypothesis

3.2.3.3.1. Model Description

This module context is not suitable for direct energy balance prediction. First because this would not align with PIXEL's energy tool objectives. One of the key features of this tool is to enable user to test scenario (about

[19] http://re.jrc.ec.europa.eu/pvg_static/en/manual.html
[20] https://www.nrel.gov/docs/fy15osti/64102.pdf

schedule, machine consumption or other). Grid load's prediction must reflect this scenario. Second because there is no historical data set for such statistical approach.

This module will then make predictions based on the difference between the electrical consumption time series and the photovoltaic production time series.

3.2.3.3.2. Limitations and assumptions

A limitation concerning this module is a potential sum of two errors from the inputs.

Furthermore, if one of the time series is incomplete, an aberrant behaviour may occur. Indeed, if one of the series has no value to match a time step index of the second series, it cannot be calculated the value for this index of time step.

3.2.3.3.3. Input data

The two inputs are respectively:

1) The electrical consumption time series from the Energies Consumption Module's output
2) The electrical production time series from the Electricity Production Module's output

3.2.3.3.4. Output data

This module output will be a JSON comprising two-time series:

1) Electrical grid load (i.e. production – consumption)
2) Electrical balance (i.e. production / consumption)

3.2.3.3.5. Model parameters

If alerts are to be issued when threshold values may be exceeded, these thresholds must be provided as parameters.

3.2.4. Modules usage and interoperability

The main modules usage and interaction with others PIXEL tools are illustrated in Figure 17 20. The most remarkable interactions are:

1) The use of port's activities scenario as input,
    a. generated by the scenario manager,
    b. in the future eventually supplemented by the transport model.
2) The consumption model output transmission to the pollutant emissions quantification model.

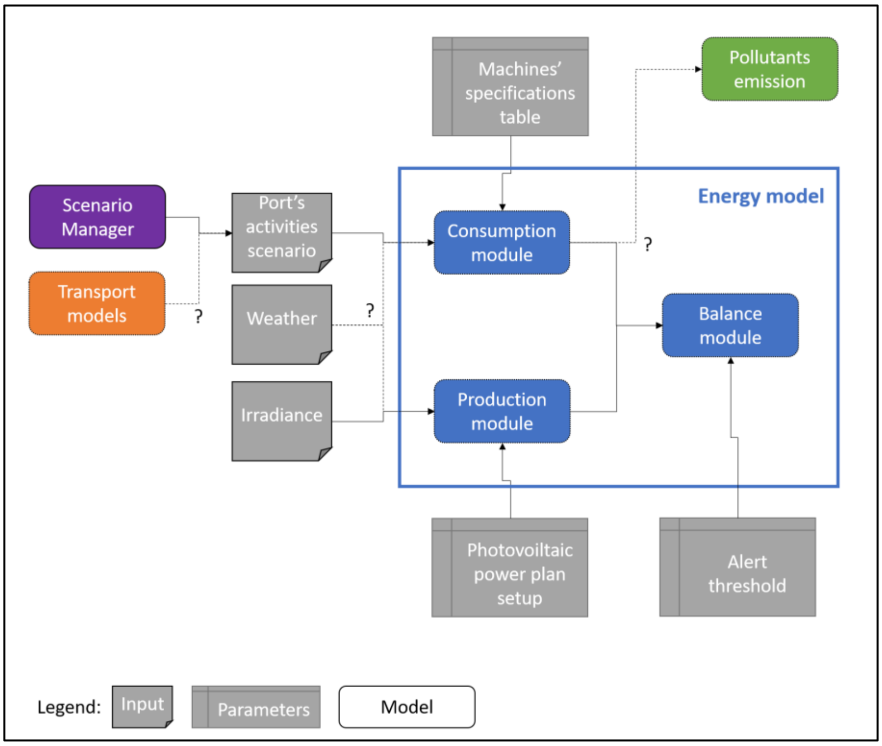


Figure 17. Energy modules' interoperability illustration (draft)

3.3. Hinterland multimodal transport Models

3.3.1. Context

The port activities regard mainly the loading and unloading of goods from and to the ships as well as the handling of the cargo in the port warehouses/stocking areas carried out by port operators. There are no production or transformation activities inside the port. The general services are supplied by different subjects that have specific attributions over the port (Port Authority, Maritime Authority, Police, Customs Agency, etc.) in accordance to the current legislation.

The incomplete monitoring system of the freight traffic in the Friuli Venezia Giulia Region, originated from the aforementioned:

i) no common regional plans

ii) no interoperable information systems between the regional stakeholders (included Monfalcone Ports and SDAG) causes a reduced use of the railway and inlandports services with the consequent congestion of the ports areas and of the motorway and urban roads with a highest risk for the citizens' mobility.

This trend could be modified using a system that put in communication and cooperation all stakeholders of the Region in order to increase the knowledge on the typology of the traffic (from, to, what, when) and to manage the traffic using all available resources (ports, inland ports, railway) in order to reduce the impact on the traffic, addressing the traffic toward multimodal transport, in particular railway, and improving the services provided to the truck drivers using all regional resources such as inland port service provider.

The reader should note that this is some first insights about how modelling transport and this first work will be completed in the second version of this deliverable after a deeper investigation and analysis of available data

3.3.1.1. Addressed issue

In this chapter we're going to focus on pilot's wish list in order to better tuning the Hinterland multimodal transport model.

The model should be able to collect data needed and transform it in a trucks flow inside port area and indirectly in a slot parking demand in order to identify when and how trigger events to fulfil pilots wishes

Hinterland multimodal transport model should also be able to collect and normalize useful data to calculate port's PEI. To do so we're going to analyse a specific scenario in order to see how the environmental impacts improve using different transport mode (rail instead road) carrying goods from Monfalcone's port to destination.

In the table below, we can see what Port of Monfalcone want in order to improve its performance inside PIXEL purposes.

Table 12: Port of Monfalcone modelling needs

Id	As a/an	I want to ...	So that ...
Port of Monfalcone	Gate/Access Manager	Have automatic predictions of parking occupancy in the port entry parking area using the actual parking occupancy, the port gate flows and the vessels scheduling and historical traffic data on a daily basis with "some" hour range	Truck operators can be notified of congestion of port access and parking availability / predictions if they overpass certain threshold, as well as other stakeholder (municipality, police), in order to evaluate proper actions to minimize the issue and port-city interference

			In case a parking is full (or almost) and the automatic predictions of parking occupancy forecast an increment in traffic flows and parking needs, truck drivers/operators can be notified of it and linked to SDAG in order to reroute their parking destination towards the interport or delay their arrival to the port/parking area

Table 13: SDAG modelling needs

SDAG	Parking area manager	receive automatic alerts of trucks diverted to SDAG from the port of Monfalcone	I can check automatically the availability of parking slots and/or reserve + address trucks to the different parking areas
		have an automatic booking system for trucks that are diverted to SDAG	I can reduce/optimize manual work from the internal personnel and the use of resources
		receive automatic alerts of ADR (dangerous) transport coming to SDAG	I can reinforce the security (in a dedicated parking area) related to ADR transport and/or divert trucks in other infrastructures
		have anticipations or simulation of the traffic congestion in the port/sorrounding areas (through a system that put in communication more stakeholders thanks to SILI platform, for example: Autovie Venete and other authorities)	I can estimate the n° of trucks coming to SDAG and I can evaluate the use of all available resources (ports, inland ports and railway) to address the traffic towards other multimodal transport and support the decision making in addressing the trucks towards Monfalcone or other infrastructures. Furthermore, I can improve all the services offered to the truck drivers in the inland ports

3.3.1.2. Data available for modelling and data analysis

3.3.1.2.1. Typology, validity, reliability, completeness, accuracy and integrity of data-based

There are a lot of different data we need to gather in order to define a model able to fulfil the transportation use case and able to give an answer to pilot's wish list.

We need to collect the data show below:

- Planned arrivals and departures of vessels (in a time interval);
- Planned arrivals and departures of trucks ((in a time interval);
- Real time parking occupancy;
- Real time situation on port's gates.
- Wheatear situation on port premises;
- Road traffic situation (include Authority's order).

- Complexity of loading and unloading activities in order to estimate time truck will be stuck inside port area (e.g.: unloading activities requiring special equipment or large temporary storage area influencing trucks flow inside port area);
- Historical data related to arrivals and departure of vessels

Planned arrivals and departures of vessels: We need to extrapolate the number of vessels ingoing and outgoing for every single day at least for the week incoming. For each vessel a set of data is associated like identification of vessel, type of goods carried, estimated time of arrivals and estimated time of departure, number of tons carried;

Planned arrivals and departures of trucks: We need to extrapolate the number of trucks ingoing and outgoing for every single day at least for the week incoming. At each trucks a set of data is associated like identification of trucks (plate number), type of goods carried (the most important thing is to differentiate between ADR and other goods), estimated time of arrivals and estimated time of departure (even the time of stop inside port area could define the need of a slot inside parking area).

Real time parking occupancy: This data, coming from a camera ASPM is going to install over parking, give us real time information about the currently slot parking availability. This is the most important data in order to estimate not only real time occupation but even to identify slot availability trend line (historical of parking slot availability).

Real time situation on port's gates: By using a camera installed over port's gate we are able to estimate if there is a congestion or an important flow entering port's gate. This information gives us an idea of how is going to change parking lot demand in a short term;

Wheather situation on port premises: These data are useful to understand if trucks incoming to ASPM is going to have the possibility to reach it by using road infrastructure. This is not only a real time alert (is snowing and the road to ASPM is closed or completely congested) but even a forecast alert (the weather forecast tell us is going to strong snow in the next 8 hours, it's very likely road Authority is going to stop heavy traffic in the next hours).

Road traffic situation (include Authority's order): Sometimes happens Authority is obliged to close some road due to car accident or some planned maintenance work. This information is useful to understand if a set of trucks planned to arrive in a certain time interval will really arrive or not, helping decision maker to choose if divert trucks traffic to SDAG. Even trucks exiting from port using that road could be stop inside port (and then inside parking area);

Historical data related to arrivals and departure of vessels The analysis of historical data related to arrivals and departure of vessels should pay attention to some correlation between certain vessels loading and unloading and the availability of parking slot. Model will be able to transform this correlation in a parking slot demand.

3.3.1.2.2. Source provider

Each set of data depicted will be collected from a specific source. Sometimes data are available and managed by port's Authority (ASPM and SDAG are the pilots for this model), in these cases we have the full availability to use them inside the project without specific authorisations. Other times data are not managed by port's Authority and we need to ask other stakeholders involved inside port area (such as import/export companies, port operators, …). In these cases, we could have some problems using them inside project (privacy problems).

Planned arrivals and departures of vessels: PMIS and PMIS 2 systems are the platforms from which we are going to download data related to vessels. These data are not managed by ASPM and we need some authorisation to use them inside PIXEL project.

Planned arrivals and departures of trucks: this data cannot be used as there are not available but can be forecasted with a prediction from both PMIS and SILI systems (both actual and historical) or ASPM sailing list database.

Real time situation on port's gates: This data are monitored by SILI system.

Wheatear situation on port premises: OSMER data can be used http://www.osmer.fvg.it/mare.php?ln=#/.

Road traffic situation (include Authority's order) This still need to be specified.

Historical data related to arrivals and departure of vessels: PMIS or ASPM sailing list database

3.3.2. State of the art

3.3.2.1. Literature review

Some good literature already exists in transport modelling (Tatineni 2005, Dimitrijević 2012, Comi 2010, Beuthe 2000). This literature will need a deeper investigation and will be added in the next version of this deliverable.

3.3.2.2. Existing tools and software

There are a lot of different software and tools working on multimodal transport and modelling, but nothing strictly related to freight transportation "from and to" medium and small ports. Most of them are focused on city premises and on persons transportation.

PTV Visum http://vision-traffic.ptvgroup.com/en-us/products/ptv-visum/

One of the world's leading traffic planning software designed for transport planners to empower cities. It consistently models all road users and their interactions and has become a recognized standard in the field of transport planning. Transportation experts use PTV Visum to model transport networks and travel demand, to analyse expected traffic flows, to plan public transport services and to develop advanced transport strategies and solutions.

WOLF (HUPAC) http://www.hupac.com/EN/Platform-WOLF-9d39b000

WOLF is the Hupac platform to manage all phases of combined transport, from booking to collection, from tracking & tracing to info on any hiccups along the way. WOLF can be accessed on any device (PC, smartphone and tablets) and using any browser (Chrome, Firefox, Safari, Internet Explorer, etc.). WOLF, acronym of Web Oriented Logistics Framework, is the portal that gathers all the data and applications our customers need to manage their shipments in a simple and fast way. There are also many functions for our partners (terminals, railway undertakings and wagon workshops) letting them manage traffic flows more easily. With WOLF it is possible to: 1) specify who, within their own organisation, shall access the various functions, 2) book shipments; 3) create standard forms for routine booking, 4) access tracking & tracing tools, 5) view shipments at the terminal, 6) specify the driver authorised to collect a shipment from the terminal, 7) view shipment statistics, etc. WOLF also offers a CO_2 calculator that can be customised to the traffic volumes of individual customers. The system performs an immediate comparison with road transport and produces a certificate directly downloadable and printable in PDF.

TMS (Generix Group) https://info.generixgroup.com/FR-DownloadproductsheetTMS.html

3.3.3. Working Hypothesis

3.3.3.1. Description of the model

The hinterland multimodal transport model has to take into account different data in order to manage pilot's wish list and at the same time to collect data useful to calculate emissions quantification.

The first goal relates to collecting inherent data: parking occupation, in going vessels list, outgoing vessels list, in going trucks list, outgoing trucks list,…

To build up this model we need to consider several aspects as shown in the figure below:

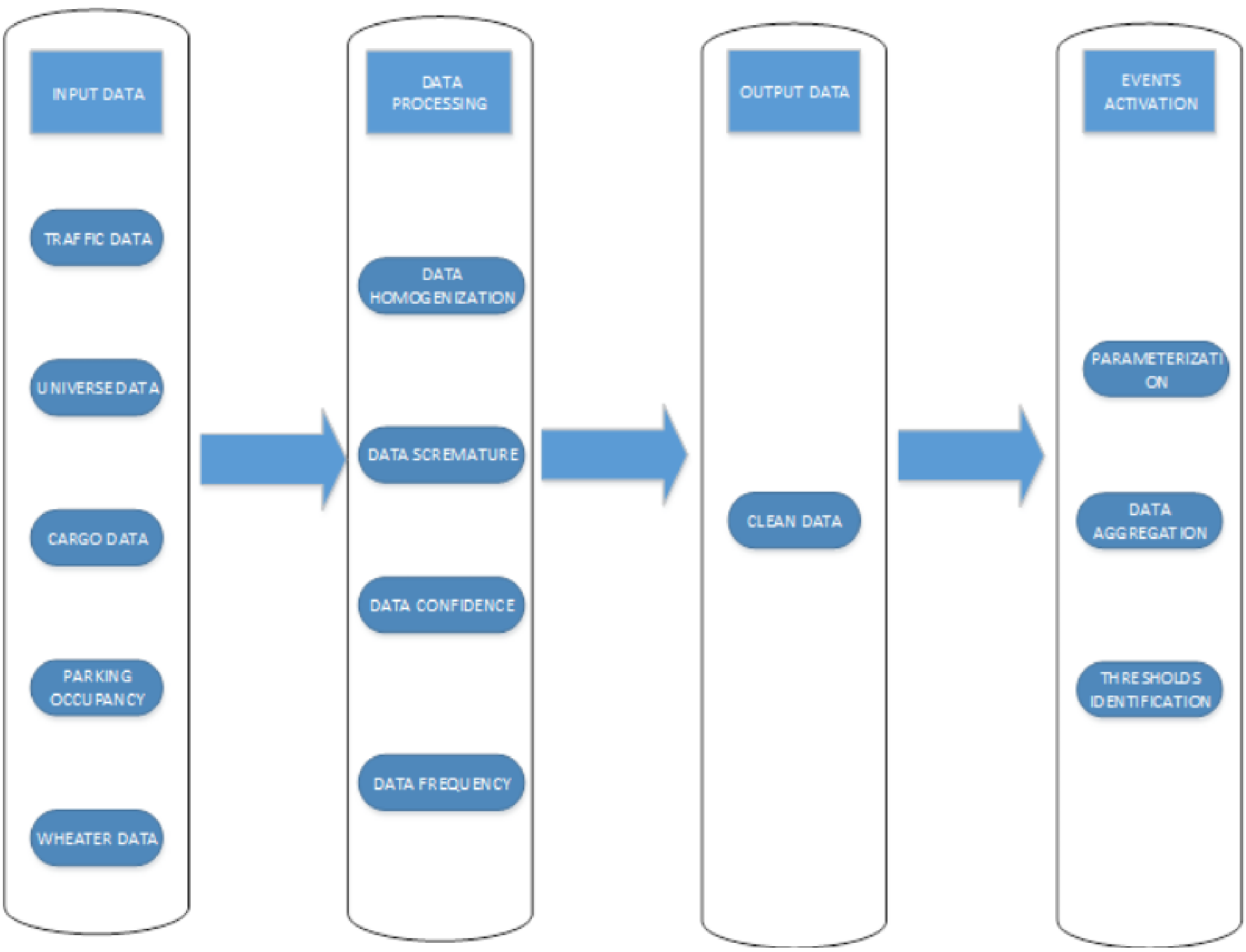


Figure 18:Hinterland multimodal transport model

There are a lot of different data (each kind of data will be in deep analyse in the following chapters) to consider, to harmonize, clean and aggregate in order to trigger events.

So, once we gathered all data needed (INPUT DATA) we have to process them (DATA PROCESSING) so to have a set of clean data (OUTPUT DATA).

With the aim to keep the model as generic as possible and have the possibility to use it even for other pilots three steps are needed:

- PARAMETERIZATION: each specific condition related to model universe (road distances, rail distances, multimodal transportation nodes, goods transported, public authorities rules…);

- DATA AGGREGATION: each specific reality has its own data coming from different sources. In order to trigger events sometimes we need to aggregate them (to reroute a truck from ASPM to SDAG we need to know at the same time data coming from traffic source, data coming from parking occupancy sensor and so on…)
- THRESHOLDS IDENTIFICATION: In order to trigger events, we need to define when the event must be triggered. For instance, we can decide to divert a truck coming to ASPM when parking occupancy is greater than 90%. So 90% is the threshold beyond which trucks will be diverted.

Managing these 3 steps allows to use a model as a DSS (decision support system) for stakeholders involved, and at the same time allows to calibrate the model for different situations, different universes (different pilots).

In terms of emissions quantification, we are going to focus on how emissions, inside and outside port's premises, change due to different transport modes. In the following, we analyse a "use case" that is actually in a start-up period.

Steel slabs arriving at ASPM by shipping with the aim to get to "Aussa Corno" industrial district (Metinvest Trametal, Technosider are the enterprises involved in this business).

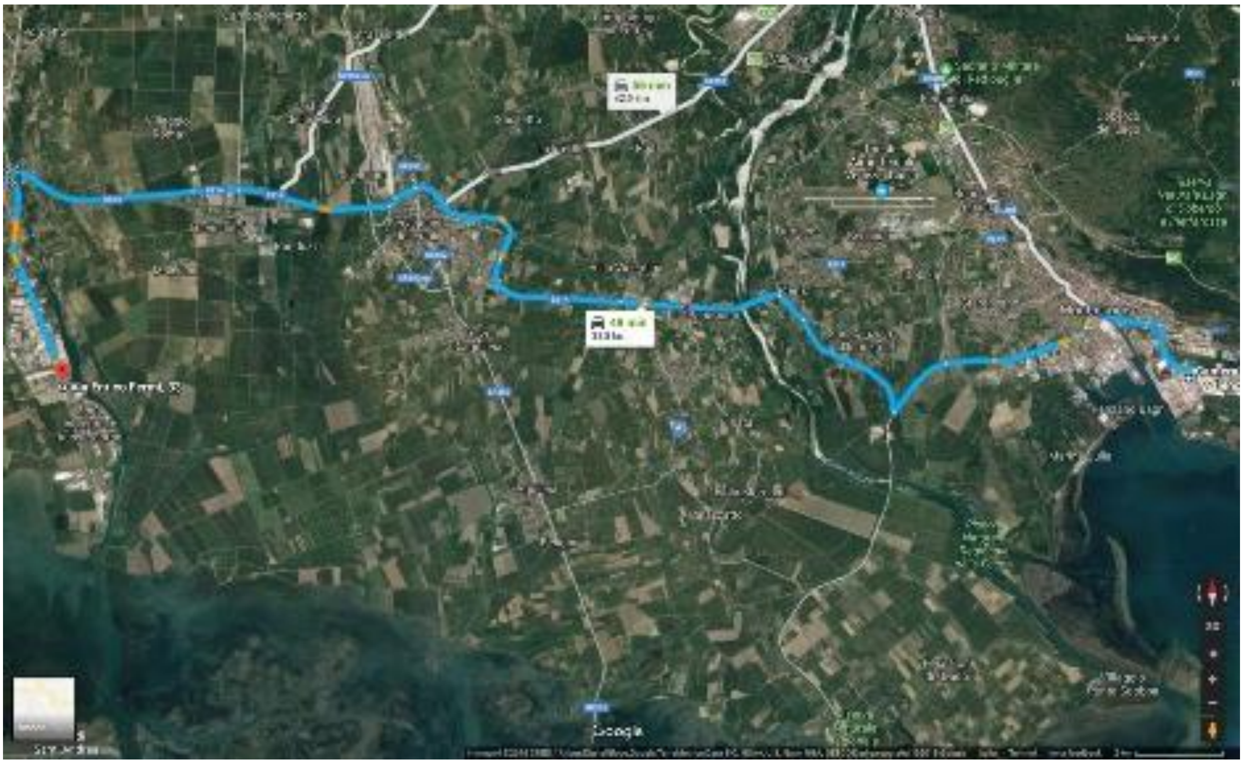


Figure 19: From Monflacone's port to "Aussa-Corno" industrial district by road

There are 2 potential scenarios:

Scenario 1: "Steel slab" arriving to Monfalcone's port by shipping. Slabs are handled by cranes and put into trucks.

Trucks are driven by roads form Monfalcone Port to "Aussa Corno" industrial district (almost 40 km away) passing through a dozen of small and medium villages making growing up congestion traffic jam and potential accidental crash (social security decrease). Most important is the heavy weight of the cargo strongly damaging road infrastructure during truck's trip causing very high social costs.

Scenario 2: "Steel slab" arriving to Monfalcone's port by shipping. Slabs are handled by cranes and put into a cargo train.

Trains are driven by rail from Monfalcone Port to “Aussa Corno” industrial district (almost 40 km) without passing through a dozen of small and medium villages, avoiding the growing up congestion, traffic jam and potential accidental crash (security decrease).

In order to evaluate in the best possible manner, the pollution made by trucks in terms of CO, NOX, PM, … emissions, we are going to use Copert method (https://www.emisia.com/utilities/copert/documentation/, interpolate data from experimental tests).

Day Emission will be function of road length (Km), number of trucks involved by day and emission factor (each kind of vehicle has its own emission factor depending on kind of fuel, weight, model, traffic and so on, but we are going to use a standardised diesel truck emission in order to simplify).

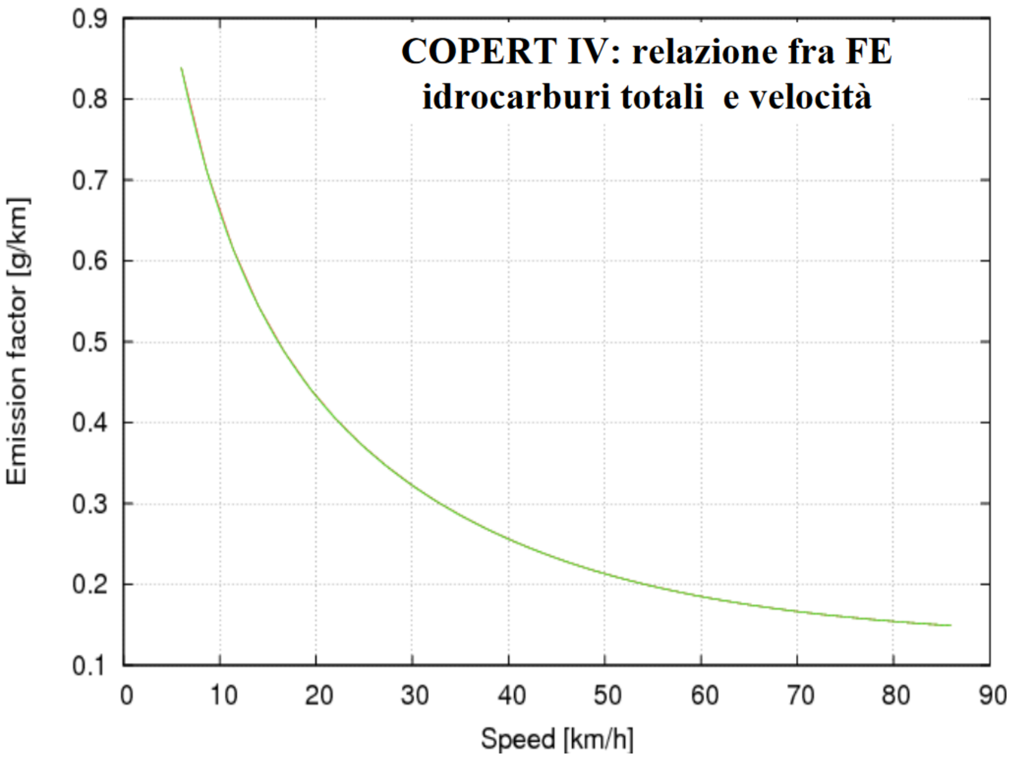


Figure 20: Illustration of COPERT IV Methodology

As one can see from the figure above the more traffic is the lower will be the speed of the trucks. Lower speed implies higher emissions. This is true not only for trucks involved in the transportation but for all vehicles involved in that traffic area. So, reducing trucks carrying goods by road reduces pollution directly (we have not trucks on the streets polluting the area) but even indirectly, reducing traffic jam and congestion the average speed of the whole vehicles involved on the streets will be higher and at the same time emissions will be lower.

Due to the weight of a single slab (almost 15 tons each) the transport agent is able to load only 1 slab (2 is maximum but in that case the transportation is not ordinary no more and they must ask for permissions to authority in order to access to road infrastructure) for a single truck. This business involves not less than 130 trucks per week.

3.3.3.2. Limitations and assumptions

The model should show ASPM how to use resources in order to cope with traffic congestion, weather, etc. that can affect the parking occupancy and then the port operations and thus the environmental impact. To be included in this modelling:

- Traffic flows;
- Provision of ships arrival;
- Road congestion;
- Data coming from the SILI system (road status, how many trucks passes through the SILI gate (1 in ASPM, 1 in SDAG, other throughout the region);
- Data coming from the videocameras system (occupancy sensor).

The model is going to operate inside a predefined universe involving:

- Port of Monfalcone;
- Hinterland hub (SDAG);
- Aussa Corno industrial district (slabs use case final destination).

So, every data involved in the model concerns an area about 30 km of ray including the 3-spot mentioned above. So we consider every parameter needed (traffic load, trucks, vessels, pollutions, …) as inside the system or outside the system depending on where the parameters are measured or estimated. Therefore, the only events considered will be events that happen within the model universe.

3.3.4. Models usage and interoperability

To estimate the global pollution produced by road delivery we need to know how a single truck pollutes during the trip from origin (ASPM) to final destination ("Aussa Corno" industrial district)

- Linear traffic equation: E=N*L*EF
- E=Emissions per week (in terms of NOx, PM10, CO);
- N=number of trucks involved in the business in a single week;
- L=Length of the path between origin and destination;
- EF=Emission factor (it depends on type of vehicles, type of engine, weight carried on…)

Applying the algorithm into scenario emissions factor will be use the estimated global pollution per week. For example, considering a diesel truck we have these EF values:

- NOx = 6.444 mg/km; CO = 1.101 mg/km…
- Setting the round trip length to 80 Km and considering 130 trucks per week we estimate the following NOx global emission:
- E=80*130*6.444=67 Kg of Nox (weekly)

Same process could be applied for other kinds of pollutants. All these elements should be very useful in order to better identify port's emission due to traffic.

3.4. Environmental Pollution Models

3.4.1. Context

Cargo handling within ports, loading and unloading cargo undeniably involve emissions of pollutants (in air, water and soil). For example, loading or unloading a cargo of dry bulk can cause a significant amount of dust in the atmosphere. Liquid cargo can bring emissions into the water. Thus, the sources of emissions into the atmosphere, water and soil generated by the supply chain of cargo are not negligible and have direct effects on the port environment.

For now, one of the first needs of the ports in the PIXEL project related with environmental pollution is to be able to quantify the different emissions of pollutants related to their activities. This first emission inventory step is necessary in order to correctly identify the sources, the types of pollutants, their frequency of emission, their quantity, etc. Of course, this emission inventory task is linked to the energy and transport aspects that have to be able to identify certain sources of emissions. For example, Hatzopoulou et al (2010) have proposed to link an activity-based travel demand with the traffic emission and dispersion models. Such approach could be also used in PIXEL. This inventory will also be based on a good knowledge of the cargo supply chain.

Once this inventory will be done, under PIXEL several modelling tools will be used to forecast different pollution end-points in time and space with the aim of assessing how pollutants, once they enter the environment, behave.

3.4.1.1. Addressed issue

The specific type of emission inventories that will be built will depend on the identification of the significant environmental aspects by the ports. However, based on the current understanding of the problem the following emission inventories will likely have be built for the ports:

- emissions to the atmosphere,
- emissions to the seawater,
- noise emissions,
- production of waste,
- light emissions.

Based on the user stories the modelling tools will be applied in order to predict the impact of emissions sources on the environment. We will be addressed modelling at local or possibly regional scales (up to 100 km in diameter) but the global behaviour of pollutants will not be addressed, and it is beyond the scope of this modelling exercise. Indeed, the needs of the ports are more focus on the macroscopic effect to understand to which area of the city the pollutants will be impacted than on the fine understanding of the reactions and interactions between pollutants. We are well aware that not taking into account the reactive phenomena will distance us from the reality and this choice constitute a limit of the models set up. However, these less accurate models will be easier to implement and better meet the needs of ports.

Air pollution is one of the main concerns expressed by ports in the PIXEL project. Indeed, many sources of emission (often mobile sources) are present in the ports and reject pollutants including particles matter, oxides nitrogen, oxides sulphide, monoxide of carbon, etc. Regarding dispersion in the atmosphere and the type of pollutants, for now it seems that particulate matter (PM) is the most important pollutant that ports want to address. The second point of interested of ports is relating with noise pollution.

Thus, because PIXEL is use-case centric, we will initially focus on setting up models on these two themes. However, we are well aware that emissions into water and soil are also important and that their modelling could also help ports reduce their environmental impacts. Nonetheless it is worth noticing that dispersion models of pollutants in water and soil require input data which are not currently available in ports and which would require substantial investment. Moreover, the dispersion models in water and soil can quickly become too complex to obtain a satisfactory accuracy and would require a time of implementation which would not allow us to treat properly the elements put forward by the ports. If ports expressed a clear need of the prediction of soil and water pollution, we will try to help them to clearly identified what they could do with their available data.

3.4.1.2. Data available for modelling and data analysis

Emissions to atmosphere

The data that will be used for modelling pollution dispersion are mainly meteorological data coupled with data on emissions from sources inside the port.

- Emission data which will be obtained under PIXEL will be derived from proxy data (eg. energy consumption) and will thus be less accurate than data obtained from direct measurements.
- Data which will be obtained from direct measurements include some of the meteorological data such as wind speed.
- For noise level estimations there are direct measurements available made by the ports.

Emissions to water

Like in atmosphere, meteorological data are needed for modelling particles transport and dilution. In sea water, the dispersion is linked with dynamic movement of the water column. This movements are the result of several interactions: wind in surface, wave swell, tide, currents, bathymetry and containment level of the dock…

Dynamics models in costal water are not easy to use. The tools (http://www.coastalwiki.org/wiki/Modelling_coastal_hydrodynamics) existing have high level of precision and need a lot of data.

Noise emissions

The data needed to noise mapping are:

- Geographical information:
  - Spot heights and contours
  - Residential and industrial buildings
  - Other obstacles in the study area (e.g. containers' formations)
  - Location of noise sources
  - Location of noise sensitive areas
  - Identification of surface characteristics of ground
- Industrial noise sources:
  - Location of every relevant industrial source (cargo handling, container handling, cranes, vehicles, auxiliary equipment) including height.
  - Working hours of every source considered for day, evening and night period.
  - Sound power level of each industrial source.

The source provider of all the input data (both proxy and directly measured data) is the port. For other data such as dispersion coefficient, emission factors, etc. data will be derived from the literature. For certain parameters historical data sets exists, such as meteorological data and noise measurements. But for other parameters such as data on emissions or even proxy data on energy consumption could be lacking.

3.4.2. State of the art

Quantifying air emissions

Each port should have an Air Quality Environmental Monitoring Program to identify, assess and quantify port's significant air emissions and develop appropriate actions and operational techniques to protect and improve air quality within the port area.

Air emissions occur at different locations of the terminal as a product of various operations, i.e. energy consumption for the purpose of performing port transhipment processes and operations (Table 12).

In general, emissions represent quantification as a function of port activities for evaluating the influence of port terminal processes, as well as a function of vessel in the port, road trucks and railway power demand. Based on the actual consumption of different energy sources over a period of time (working month) for carrying out the core activity of the port terminal, the emission factors calculated by the emissivity of the pollutant in the air were measured using the observed parameters, which are the input data of the model. All mentioned estimated emissions are expressed in kWh multiplied by an emission factor, where the emission factor is expressed in terms of grams per kilowatt-hour (g/kWh).

Table 14: A list of potential indicators of emissions into air

Indicator symbol	description
CO2	carbon dioxide emissions
NOx	nitrogen oxide emissions
SOx	sulphur dioxide emissions
CO	carbon monoxide emissions
PM	particulate matter emissions
VOC	emissions of volatile organic compounds
GHG (other)	greenhouse gasses emissions

The methodology for assessing and quantifying all aspects of the impact of harbor processes on the environment combines emissions that affect the air from different sources during basic port activities.

Emissions into air from ships in the sea port (harbor basin) depend on the type and size of the ship and on the specifics of its energy system. In this sense, we have to differentiate between different sea-going vessels within the port boundaries from harbor crafts within the port boundaries, taking into account various modes (cruise, reduced speed, manoeuvring, hotelling). The current approach to calculating the emissions from sea going vessels utilises energy-based emission factors together with activity profiles for each vessel.

Two different procedures can be used to estimate emissions: based on fuel consumption or engine power. When fuel consumption for each phase is known, then emissions of pollutants can be calculated by using the following equation:

$$E = FC \times EF$$

$$E_i = \sum_p \left(FC_{e,f,p} \times EF_{i,e,f,p}\right)$$

- Ei = emission

- FC = fuel consumption (kg or tons)
- EF = emission factor (kg/ton),
- i = different types of polutant,
- e = different engine types (slow, medium, and high-speed diesel, gas turbine and steam turbine)21,
- f = fuel type (bunker fuel oil, marine diesel oil/marine gas oil (MDO/MGO), gasoline),
- p = the different phase of operation (manoeuvring, hoteling, cruise).

This procedure is applicable only where detailed information about fuel consumption for each ship/engine type combination in the different navigation phases is available. When fuel consumption per activity phase is not known, then a different methodology is proposed for computing emissions, based on installed power and time spent in different activity phases. Emissions can be calculated from a detailed knowledge of the installed main and auxiliary engine power, load factor and total time spent, in hours, for each phase using the following equation:

E = A x P x LF x EF x EEDI

$$E_{i,e,f} = \sum_{p} \left[A_p \sum_{ec} (P_{ec} \times LF_{ec} \times EF_{ec,i,e,f,p}) \times EEDI \right]$$

- E i,e,f = E = total emission in kg/A
- A = the activity, is the time (h) the ship is cruising, manoeuvring or hotelling; time can also be
- calculated as the ratio between distance (km) and speed (km/h);
- E = emission
- FC = fuel consumption (kg or tons)
- EF = emission factor (kg/ton),
- P = the Maximum Continuous Rating, indicates the installed engine power of the ship
- i = different types of pollutant,
- e = different engine types (slow, medium, and high-speed diesel, gas turbine and steam turbine)22,
- ec = engine category (main, auxiliary),
- f = fuel type (bunker fuel oil, marine diesel oil/marine gas oil (MDO/MGO), gasoline),
- p = the different phase of operation (manoeuvring, hoteling, cruise),
- EEDI = Energy Efficiency Design Index23.

From the moment trucks enter into the port, including the time spent at the port, the use of traffic service equipment, until they exit the port, it is necessary to estimate the amount of air emissions caused by the operation of trucks in the port. The type of fuel consumed by trucks should be taken into account. They are mainly the same power and the same fuel used, so the emission factors are the same, except for those using LNG fuel.

E = A x EF x N

A = FC/T

- E = total emission in kg/T
- A = the activity

[21] Slow speed engines: less than 130 rpm, medium speed engines: between 130 and 2,000 rpm, high speed engines: greater than or equal to 2,000 rpm

[22] Slow speed engines: less than 130 rpm, medium speed engines: between 130 and 2,000 rpm, high speed engines: greater than or equal to 2,000 rpm

[23] The methodology of EEDI calculation, based on the relative CO2 emission from ship power system and on the benefit for the society, is defined as a method that can be widely used to evaluate the ships energy efficiency and environmental impact through the Index of Energy Efficiency and Environmental Eligibility.

- EF = emission factor (g/kg fuel),
- N = number of trucks,
- T = the working time in the port (h) of a truck within the harbour,
- FC = fuel consumption (g/kWh).

Similarly to road traffic, an estimate of the impact of rail traffic on the air in the port is made. From the moment the train composition enters the port, including its time spent in the harbour, the use of equipment for transport services until it leaves the port, it is necessary to estimate the amount of air emissions caused by the work of locomotives in the port. They are mainly the same power and the same fuel used, so the emission factors are the same, except for those using LNG fuel.

Total emissions within the harbour area, coming from diesel trains, are calculated based on the following:

$$E = EF \times d \times c \times N$$

- E = total emission in kg/T
- EF = emission factor in g/kg fuel
- d = distance of rail transport within the harbour (km)
- c = diesel consumption in kg diesel/km
- N = number of diesel trains
- T = working time in the port (h) of a train within the harbour

Air pollution dispersion model

To model a phenomenon, two types of approaches can be considered: statistical modelling (empirical) and deterministic modelling (physical).

The first approach uses data describing the system's variables (concentration measurements, emission estimates, meteorological observations, etc.) in an equation as the form of a linear regression, without involving any kind of chemical and physical environmental notions. For example, Baawain and Al-Serihi (2014) discuss air pollution prediction based on an artificial neural network. The data set they use covered a period of four year with hourly measurement of PM_{10}, O_3, CO, SO_2, H_2S, NO NO_x and NO_2. They also monitored meteorological parameters simultaneously (wind direction, wind speed, relative humidity and air temperature. Even though they showed good results, the use of such approach required a huge data set and need to be validate for different areas. Currently, PIXEL partners do not have in their possession such data set for the different ports so this kind of approach will not be used.

The second one is based on the formulation of physical and chemical mechanisms and on the numerical resolution of equations based on physical laws. This equation governs the mechanisms controlling the phenomenon in question. The development of these models therefore requires the most detailed understanding of the processes involved. In some case, e.g. in a marked topographic environment and near the sources, the physical processes involved are both of great complexity and not completely known. A good description of mathematical urban air pollution models can be found in (Moses 1969, Cora 2003, Buske 2012, Johnson 2014).

The fact remains that, at present, purely deterministic models offer results that are relevant to decision-makers, if the boundaries are clearly defined, and their performance is regularly assessed. The following table sums up the both approaches.

Deterministic models	Statistical models

We suppose that we know the physical laws, and that we follow the evolution of variables over time.	We search for statistical relations between predictive (or explanatory) variables of the physics and the variable to predict.
Advantages - By design extrapolable. - Spatialization of the forecast. - Universality of the approach.	Advantages - Fast prediction and generally satisfactory. - Implementation more "simple", without integration of physical and chemical laws governing the phenomenon.
Drawbacks: - Quantity, quality and diversity of data to provide to the model (emissions, wind fields, boundary conditions, topography ...). - Difficulty going down at very fine scales (local under 1 cm) and in marked topographic environments (strong slopes). - Laws governing different phenomena at these scales, still poorly known today.	Drawbacks: - Need a good documented database. - Provide little explanatory information (Black Box). - More difficult to extrapolate for prospective analysis (use in the domain already observed).

Despite the difficulty of implementing deterministic models and the technical risks that are linked with (Dimov 2004, Loague 1998), we are moving towards the choice of deterministic model in the context of PIXEL. There are several reasons for this: 1) we want to set up models that can be replicated in different ports, 2) we do not have the necessary database to use statistical models, 3) we want explanatory models.

Deterministic models fall into three categories according to their calculation approach: Eulerian, Lagrangian, and Gaussian models. In a simplified way, these models ask for different sources (sources of pollution, geography, meteorology, etc.) as data inputs. They solve the equations governing atmospheric phenomena and give a mapping of pollutants and establish forecasts.

The Eulerian approach describes the distribution of a substance or a molecule, in a fixed system, according to the characteristics of this system. The principle of the Lagrangian approach consists in following a substance emitted at the source. Eulerian models discretize the mesh atmosphere in 3D. They are also called grid patterns. Lagrangian models are also called trajectory (or plume) models because they solve a system of equations in a referential related to the displacement of a column of air in the path of a plume. The air column moves according to the meteorological conditions (usually pre-calculated or measured, unlike the Eulerian models) considering simple transformation processes, such as linear chemical reactions and deposition.

These two types of models have the advantages of a complete resolution of the equations, an accurate modelling of turbulence and consideration of complex phenomena. If the meshes of study are fine, then these models offer a better representation of the physics. Thus, the main drawbacks lie essentially in the fact that spatial scales are often limited. The computation times depend on the complexity of the model used, the spatio-temporal resolution chosen by the user, and the calculation means implemented. Generally, 3D models require supercomputers and parallel computation on several processors, which does not make them easily accessible. In addition, these models are very sensitive to various parameterizations and input data. Finally, Eulerian and Lagrangian models require very precise knowledge for their use and design. For this reason, we think that they are no adapted at all to be used in the PIXEL framework and that we should consider the last type of deterministic model.

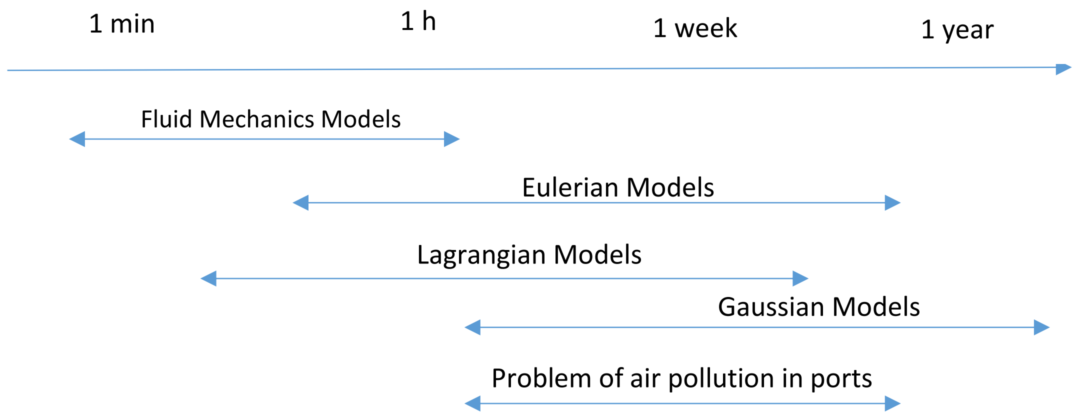


Figure 21: Typology of air dispersion models

Gaussian models (ADMS, AERMOD, ARIA Impact, etc.) are the most used ones to model air quality near areas close to sources of pollution (Lonati 2010, Gibson 2013). The principle of Gaussian atmospheric dispersion is based on a simplified mathematical description of the dispersion equations of a substance in the air. At the base, the substance is dispersed by the sole action of the fluid that carries it, the air. Then the transport and the diffusion will intervene by the action of the wind and the mechanical and thermal turbulence. In other words, this type of model considers that a specific emission (a plume) is dispersed in width, especially since the direction of the wind varies (strong standard deviation), and in height, especially as the air is unstable. The purpose of these equations is to determine the concentrations of the substance according to parameters such as emissions, weather conditions, or other parameters related to the earth's surface (roughness and land use, for example). Generally, a weather processor is integrated with the Gaussian models, which makes it a single software, relatively easier to exploit.

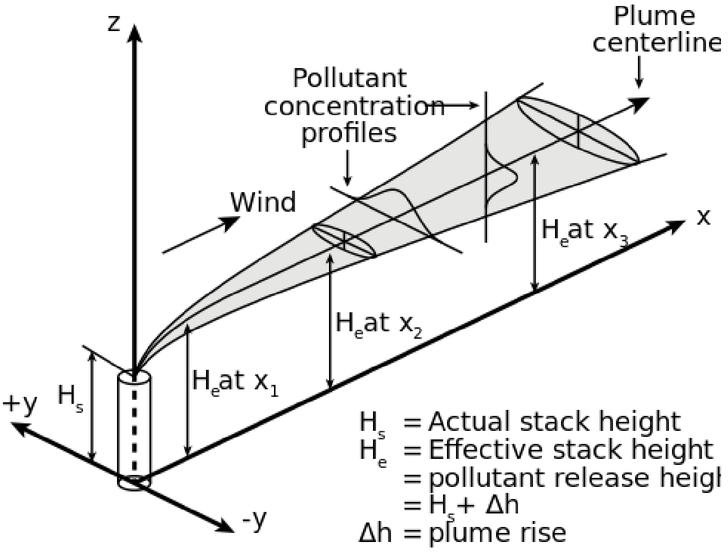


Figure 22: Schematic figure of a Gaussian plume.
Source http://elte.prompt.hu/sites/default/files/tananyagok/AtmosphericChemistry/ch10s03.html

This Gaussian approach is very inexpensive in terms of calculation time (comparing the Eulerian or Lagragnian approach). So, it is possible to multiply the number of simulations carried out and have averages and statistics established on annual or multi-year meteorological databases.

In return, the parameterizations of the equations are simple, which leads to sometimes rudimentary approximations of some cases (such as the effect of the relief or the buildings, which can have significant influence on dispersal, especially on a small scale). In a first step for the air pollution dispersion prediction, we will use dispersion Gaussian model in PIXEL.

Noise dispersion model

The Good Practice Guide on Port Area Noise Mapping and Management that has been developed by the partners of the NoMEPorts (Noise Management in European Ports) is a very good starting point to cover all the aspects that relate to modelling noise dispersion.

As stated in this report and showed in Figure 18, the complexity of port's infrastructure and lots of different activities in port lead to many sources that may contribute to the ambient noise of a port area agglomeration. That is why the first step is to mapped noise inside the port to provide the port authorities with the basic information to identify source of noise.

Some previous EU Projects such as HARMONOISE and IMAGINE (https://cordis.europa.eu/project/rcn/73857/reporting/en) (Salomons 2011, Ecotiere 2012) was entirely focus on producing a new EU methodology for predicting environmental noise mapping. From that we can identify some tools and methodologies that could be use in PIXEL but this need a deeper investigation.

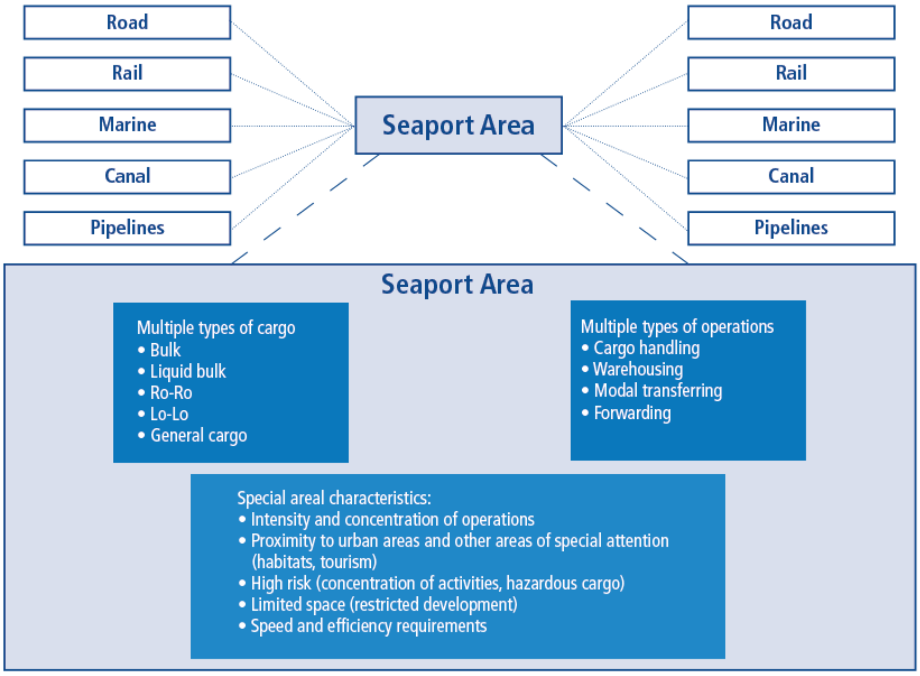


Figure 23: Seaport area characteristics

According to NoMEPorts, the following step should be respect when modelling noise in ports:

- Definition of geographical boundaries for the noise studies should include:
  - The port area where the noise is generating.
  - Residential and other noise sensitive neighbouring areas influenced by the port.
  - Areas Between the port area sources and the neighbouring noise sensitive areas.

- Definition of noise source boundaries

What is include? E.g. do we include the noise generated by the traffic (roads, railways, air traffic). The recommendation is to first start with a representative picture of the general noise situation in the ports and then try to solve the issue of the relative contribution of different sources.

- Definition of the port area noise mapping
  - Selecting the appropriate calculation methods
  - Collecting geographical information:
    - Spot heights and contours
    - Residential and industrial buildings
    - Other obstacles in the study area (e.g. containers' formations)
    - Location of noise sources
    - Location of noise sensitive areas
    - Identification of surface characteristics of ground
  - Identifying and the modelling noise sources (noise data collection is required)
  - Setting calculation parameters

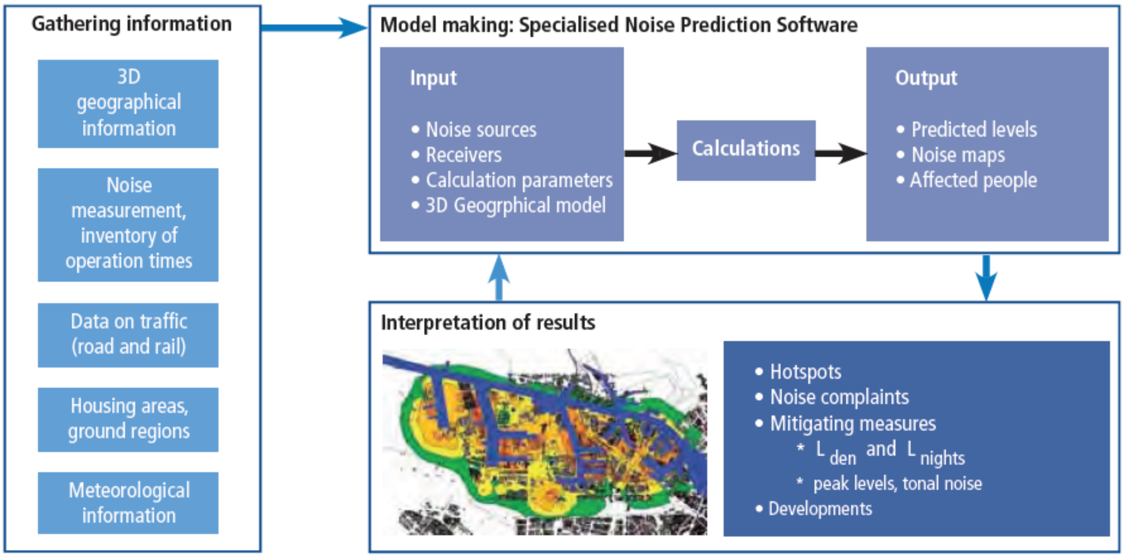


Figure 24: General schematic function of noise prediction NoMEPorts

NoMEPorts also highlight some lessons they have learned about noise data collection:

- Noise data collection can be a time-consuming exercise. It is necessary to get an overview over the input data requirements and availability.
- Gaps within the noise data can be filled by default value or following experts' advice.

In order to run a noise mapping software some first parameters must be set:

- Define the gird on which the calculation will be performed
- Define meteorological data: average of temperature, relative humidity, atmospheric pressure, wind direction and speed.

Noise calculation may be time consuming depending on the total number of noise sources and physical features to calculate. Some techniques could be used in order to reduce the computational time:

- Applying a fetching radius: a distance limit after which noise sources are not taken in considerations
- Reduce of the number of sources in use replacing complicated noise sources networks with simpler ones.

As this analysis of sound propagation models in industrial environments shows, the prediction of sound propagation and noise mapping are complex both in terms of physical modelling, model implementation, use and analysis of results. In addition, the step of identifying sources of noise pollution is an essential step and requires a lot of data. At first, we will focus on this step and then we will see how it is possible to interface with existing models for noise mapping and integrate them in PIXEL (this work is still a job to be done). We should note that if this integration in PIXEL is feasible, it could be time consuming and a lot of effort since many data will be required and a lot of model's parameters will have to be fine-tuned.

3.4.3. Existing tools and software

AEROMOD

https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models#aermod

According to our knowledge the most well-known and widely used models are the U.S. EPA air dispersion models. There are basically two models that are most often used and those are the steady-state AERMOD model and the dynamic CALPUFF model.

The AERMOD atmospheric dispersion model is an integrated modelling system comprised of three modules. The modules are as follows:

- A steady-state dispersion model designed for short-range (up to 50 kilometers) dispersion of air pollutant emissions from stationary industrial sources.
- A meteorological data module (AERMET) which calculates atmospheric parameters needed by the dispersion model, such as atmospheric turbulence characteristics, mixing heights, friction velocity, Monin-Obukov length and surface heat flux.
- A terrain module (AERMAP) which addresses the relationship between terrain features and the behaviour of air pollution plumes. It generates location and height data for each receptor location. It also provides output which is used as an input by the dispersion model to simulate the effects of air flowing over hills or splitting to flow around hills.

AERMOD also includes PRIME module (Plume Rise Model Enhancements) which is an algorithm for modelling the effects of downwash created by the pollution plume flowing over nearby buildings.

CALPUFF

http://www.src.com/

CALPUFF is an advanced, integrated Lagrangian puff modelling system for the simulation of atmospheric dispersion of pollutants.

The model has been adopted by the United States Environmental Protection Agency (EPA) in its Guideline on Air Quality Models as a preferred model for assessing long range transport of pollutants for near-field applications involving complex meteorological conditions. The system is also an integrated one and it consists of three main components and a set of preprocessing and postprocessing programs. The main components are the following:

- The CALMET component which is a diagnostic 3-dimensional meteorological model.
- The CALPUFF component (the actual an air quality dispersion model).
- CALPOST as the postprocessing package.

In addition to these components, there are numerous other components and processor which can be used to prepare the input data. The input data needed are emission data, land use and terrain data and meteorological data. The CALPUFF model is designed to simulate the dispersion of buoyant, puff or continuous point and area pollution sources as well as the dispersion of buoyant, continuous line sources. The model also includes algorithms for handling the effect of downwash by nearby buildings in the path of the pollution plumes

MIKE 3

https://www.mikepoweredbydhi.com/products/mike-3

MIKE 3 is a computer program that simulates cohesive sediments, flows, water quality, and ecology in lakes, rivers, estuaries, bays, coastal areas and seas in three dimensions. MIKE 3 was developed by Danish Hydraulic Institute (DHI) Water & Environment (Denmark). MIKE 3 models are more suitable as a simulation tools if you need to model three-dimensional (3D) free surface flows and associated sediment or water quality processes.

MIKE 3 is fully 3D model and solves the momentum equation and continuity equations in the three Cartesian directions. MIKE 3 simulates unsteady flow by taking into consideration bathymetry, density variations and external forcing such as tidal elevations, meteorology, currents and other hydrographic conditions. The hydrodynamic model provides a full 3D model representation of the water levels, flows, salinity, temperature, and density within the modelling domain.

MIKE 3 is composed of three fundamental modules: The hydrodynamic (HD) module, the advection-dispersion (AD) module and the turbulence module. Various features such as free surface description, density variations and laminar flow description are optionally invoked within these three fundamental modules. A number of application modules have been used and can be invoked optionally. These are AD of conservative or linearly decaying substances, nutrients and hygienic problems, a water quality (WQ) module describing BOD-DO relations, a mud transport (MT) module simulating transport along with erosion and deposition of cohesive material, a eutrophication (EU) module simulating algae growth and primary production. A Lagrangian based particle (PA) module can also be invoked for simulating e.g. sediment transport, tracers or the spreading and decay of E.coli bacteria.

CORMIX

http://www.cormix.info/

CORMIX is a US EPA-supported mixing zone model and decision support system for environmental impact assessment of regulatory mixing zones resulting from continuous point source discharges. The system emphasizes the role of boundary interaction to predict steady-state mixing behavior and plume geometry.

I-Simpa

http://i-simpa.ifsttar.fr/

I-Simpa is a graphical user interface (GUI) developed to host three-dimensional numerical codes for the modeling of sound propagation in complex geometrical domains. Although I-Simpa is well adapted for energetic models (ray-tracing, sound-particle tracing, theory of reverberation…), it can be extend to use ondulatory approaches. I-Simpa alone is not a calculation software, but is equivalent to a pre and post-processor for acoustic codes. One or more numerical codes must be added in order to obtain a fully functional system. At the present time, I-Simpa is delivered with two codes (TCR based on the classical theory of reverberation and SPPS based on particle tracing approach). Classical applications are room and building acoustics, environmental noise and industrial noise, but it can be easily extend to other applications concerning the sound propagation in 3D environments (interior of vehicle, sound in cavities…). I-Simpa has been initially developed as a research tool (i.e. for research laboratories), but can also be a very efficient tool for a professional/commercial use, as well as for education.

NoiseModelling

http://noise-planet.org/noisemodelling.html

NoiseModelling is a plugin of the OrbisGIS software (an open-source geographic information system) that able to produce noise maps of cities, according to the french standard method for the road noise emission and using the NMPB method for the sound propagation. The noise calculation method implemented within the NoiseModelling plugin is based on the standard French method called NMPB 2008, as a reference method to be used under the Directive 2002/49/EC relating to the assessment and management of environmental noise (Read More). Most of algorithms within the NoiseModelling plugin, mainly for the calculation of the sound propagation, are based on spatial analysis methods which allow to optimize and to reduce the complexity of the sound propagation path search in urban areas. Each part of the computation process has been split in several SQL functions thanks to the H2GIS database available within OrbisGIS. This open tool-box help the user to produce noise maps beyond the limitation of a monolithic computation software. However, the GIS environment allows to produce noise results with a high level of graphical representation, by coupling if necessary with other geospatial databases such as demographic data. For example, using GIS analysis methods, the user can easily compute a map of population exposure.

3.5. Predictive algorithms

The aim of predictive algorithms application in PIXEL is to (1) directly support needs identified by the port community and (2) provide input parameters for simulation algorithms used for PIXEL models.

1. At the time of writing this deliverable PIXEL ports requirements are being gathered and specific user scenarios elaborated. While needs for predictive algorithms could preliminary be identified in areas of road transport and energy supply from renewable sources, it is still too early to assess the real need and feasibility of those functionalities. D4.2 will provide an in-depth assessment of those needs, data availability, preliminary analysis, and prioritisation for predictive algorithms to be provided to address direct needs of the port community.

2. For the second case, provision of input parameters for simulation algorithms, needs are going to be identified as part of execution of T4.1 - T4.4. Typically, prediction algorithms would be used when there is missing data to successfully run simulations developed in T4.1 - T4.4. The main starting point for the identification of this group of predictive algorithms is the present deliverable, D4.1. These predictive algorithms will be identified and assessed similarly to the previous ones, based on priority and data availability.

The main ingredient to the implementation of predictive algorithms is the data that needs to be collected. Thus, it is crucial to describe all the available data and the data that still needs to be collected. Apart of identifying the correct needs, data (non)availability is the main risk in successful execution of this task.

Current status - Ports Needs

A preliminary overview of draft user scenarios and requirements points to some generic needs by most of the ports, while other are very specific to single ports. Deeper analysis will be needed in order to find a common denominator that would satisfy most of the ports, while still keeping in sight some specific needs.

For example, problems such as the analysis of the structure and frequency of the ships in order to predict future load are related to all of the ports and also needed by some of the main module requirements and will be as such easily integrated and extended to fit specific port needs.

On the other hand, needs such as predicting parking space availability or predicting the amount of solar energy that might be available given the data from the weather stations is very specific and will be considered separately.

However, we are in a very early stage of the assessment at this point. There are several conditions to be met in order to start the selection and implementation of the most appropriate predictive algorithms for port needs:

1. Statement of port needs will be extracted as part of the works performed in work package 3.
2. It is detected the need of historical data that should be described and made available by PIXEL project partners.
3. The application of predictive algorithms in the execution of use cases would need access to timely (on line, real time, near-real time) data.

Current status - WP4 needs

A preliminary analysis of needs for predictive algorithms in the context of modelling and simulation of port supply chains has been performed. Predictions could be used for either filling the gaps where some parameters of the port supply chain are unknown, or when there is need to simulate the performance whole port supply chain at some future point in time.

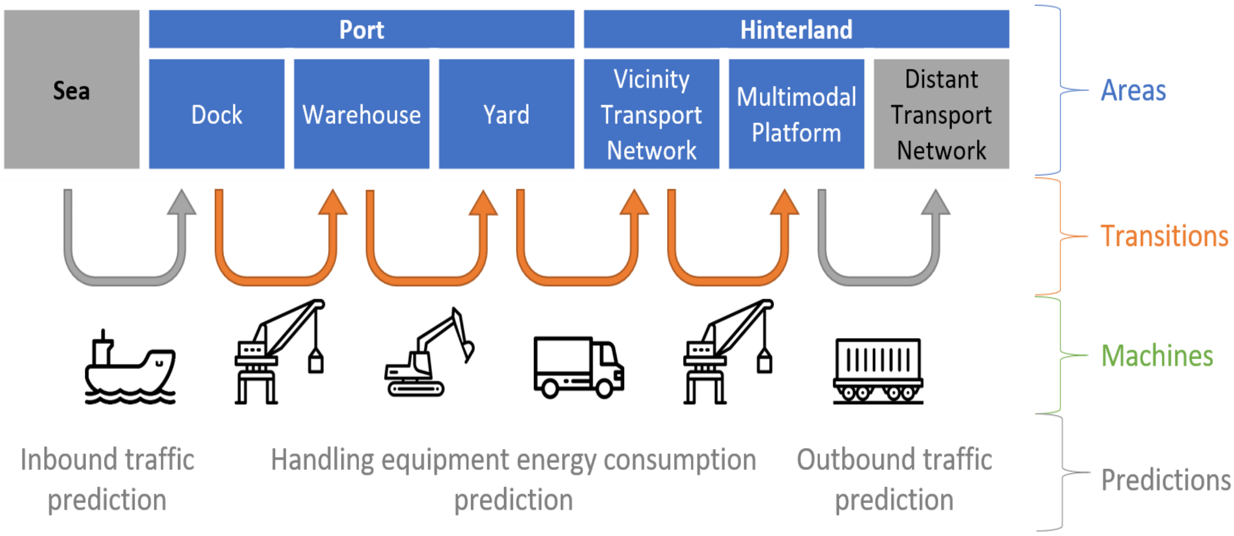


Figure 25: Predictive algorithms for port activities

In the first case the performance of a cargo handling machine of unknown properties would be predicted based on incoming cargo and historical data collected for that property. For example, energy consumption of a machine could be predicted for a particular type and quantity of cargo based on historical data about energy consumption for different quantities and types of cargo.

In the second case, incoming cargo traffic prediction, including types and quantities of cargo for a specific (future) time period would be predicted. This can be obtained by the FAL forms, Port Management Information System (PMIS) and port's policy regarding ship announcement. They can bring information about expected & effective arrival/departure time, cargo's type & quantity to handle or berth allocation. Similar data can be obtained for cargo exit. This would allow simulating the performance of the whole port supply chain for a set of output parameters.

It is our current understanding that support to supply chain simulation for different output parameters could provide benefits for several WP4 tasks. For example, energy need, environmental emissions, traffic congestion and other output parameters could be simulated by this approach.

In addition to these scenarios, other predictions may be useful for WP4 modules, such as transport network load (vehicle density, speed) or truck load in the hinterland.

However, we are in a very early stage of the assessment at this point. There are several conditions to be met in order to start the selection and implementation of the most appropriate predictive algorithms:

- Statement of needs will be extracted as part of the works performed in work package 4 (T4.1-T4.4 execution).
- Historical data should be described and made available by PIXEL project partners.
- Simulation models should be provided as T4.1-T4.4 output. T4.5 provides predictive algorithms that would provide input to simulations, but simulations themselves are not part of T4.5.
- The application of predictive algorithms in the execution of use cases would need access to timely (on line, real time, near-real time) data.

4. Future Work

This document and the associated work allowed us to define more precisely the needs of ports in terms of modelling. Although some points are still to be clarified (for example on the frequency of obtaining the data, their representativeness or their precision), the elements put forward by the ports will enable us in the following of this work to define at best the models and data analysis to put in place to meet the different needs of ports. A first presentation of the models that could be implemented in the framework of PIXEL was presented here. It remains to put in place these models, test them and validate to quantify their accuracy and scope. For this work, we may also be confronted with problems related to the available data (lack of data, poor quality, etc.). To overcome this problem, we will quickly collect and analyse the available data to minimize this risk.

The points listed below will be better addressed and developed in the next version of the deliverable:

- Data collection (representativeness, accuracy, availability, etc).
- Definition of the scenario manager (supply chain and port's activities modelling).
- Interoperability of models and how they could be used all together.
- Integration of PIXEL models in the overall PIXEL architecture (how to use them, with which parameters, calculation time, etc.).
- Fine description of the models (limits and scope, mathematical global description, numerical implementation, etc.).
- Test and validation of models.

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