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PortForward

D6.1 – Description of Port Virtual Twin Concept

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Quality Check

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Abbreviations

AIS	Automatic Identification System
AR	Augmented Reality
AMQP	Advanced Message Queuing Protocol
BImSchG	Federal Emission Control Act in Germany
DSS	Decision Support System
DTM	Digital terrain model
DOP	Digital Othophoto
GIS	Geographical Information System
ID	Identification
IED	Industrial Emissions Directive 2010/75/EU
IoT	Internet of Things
LoD	Level of Detail
MQTT	Message Queuing Telemetry Transport
KPI	Key Performance Indicator
UI	User Interface
VR	Virtual Reality
AR	Augmented Reality
MRO	Maintenance Repair Overhaul

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Executive Summary

Within the deliverable D6.1 a holistic overview of the Virtual Twin concept is given as well as a first description of a use case-specific type of a virtual Twin concept. The use case refers to the Port of Magdeburg: “Dynamic storage monitoring”.

In the first section general information, which are important for a better understanding of this deliverable, are given. A comprehensive survey about the actual situations in the ports, which focuses Virtual Twin solutions in use and in planning, is ensuring the practical relevance of the conceptual work presented here. Virtual Twin solutions, which are partially in use in the ports are presented. Furthermore, in this survey relevant working tasks and use cases were identified.

General approaches in the development of the Virtual Twin and fundamental components of a Virtual Twin are described. The integrated system model, which maps the structural and logical basis for the Virtual Twin is presented. Virtual interactive components, which leads to new forms of interdisciplinary working in VR are described as well in different variations. Use case-specific features of a Virtual Twin, referring to the situation in the port of Magdeburg, are part of the description as well.

The ongoing activities of the PortForward project show interdependencies between different project activities. Relevant interdependencies are pointed out to provide a comprehensive picture of the Virtual Twin concept in PortForward. The conceptual descriptions given here will be extended and explained in more detail in the deliverables, performed in the follow-up project activities.

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1 Introduction and general considerations

1.1 About this document

This document describes the development of a Virtual Twin Concept within the PortForward framework. Base on this document a specific virtual twin solution shall be implemented in the follow-up PortForward activities.

The first section gives relevant background information about the Virtual Twin concept and its objectives in the PortForward project. The Virtual Twin component is an integrated part of the PortForward concept. Because of interdependencies to flanking Port Forward activities, these are described as well as the Virtual Twin's place in the PortForward architecture.

In order to carry out the concept work on solid information about the initial situation, a survey about the present virtual twin-relevant solutions and expectations in the ports was performed. In section 2 a summary about this research is given. Section 3 describes relevant aspects of the use case, which is related to the Virtual Twin in detail.

Section 4 describes the development of the structural and logical model aspects of the Virtual Twin. Even if the corresponding model components can be recognized by the end user just indirectly, the development of an appropriate logical model structure is essential for the effectiveness of the Virtual Twin solution.

Section 5 describes relevant aspects about data management with the focus on the 3D model data. Based on this the concept of the virtual interactive model components are described.

In the final section 6, a conclusion about the virtual twin concept in the PortForward project is given.

1.2 A general introduction to the Virtual Twin concept

The roots of the virtual twin concept can be found in the concept of Digital Twin. This concept was shown to the economic and academic society in (Shafto, et al., 2010) first, where the following definition was given: "A Digital Twin is an integrated multiphysic, multiscale simulation of a vehicle or system that uses best available physical models sensor updates, fleet history, etc. to mirror the life of its corresponding flying twin."

With the rising of new and performant Virtual Reality (VR) technologies the emphasis of this concept is shifted more to the virtual and interactive representations of the Digital Twin solutions. "But with the advent of Cyber Physical Systems, the Digital Twin appears as a virtual representation of the physical product, a digital shadow that contains all the information and knowledge of it." (Schroeder, Steinmetz, Pereira, & Espindola, 2016).

1.3 Objectives of the Virtual Twin within PortForward

Within PortForward the Virtual Twin concept, as described in sub-section 1.2, is extended to planning, managing and operating of port infrastructures and processes. With this purpose, the use of virtual reality infrastructure models and simulations, based on near-real-time data to support planning, monitoring and operation processes is evaluated. The document will provide an approach for establishing the Virtual Twin concept for port environments.

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The PortForward approach of using interoperable IoT applications and services as the basis for the continuous and consequent collection, processing and use of data for port planning, managing and operation processes will be taken into account. These concepts will be performed in the PortForward deliverables of work packages 2–5 in detail. Content-related links to these activities in the flanking work packages will be highlighted. Generic approaches to provide an access to the PortForward services and the features of the Decision Support System DSS (D6.2) will be described.

In addition to the description of general approaches to be followed in the design of a Virtual Twin solutions, the document provides a use case specific Virtual twin design. Based on a survey of the ports situation and expectations a Virtual Twin solution for supporting the "dynamic storage monitoring" will be described generically.

1.4 Interdependencies to other PortForward activities

Because the Virtual Twin concept must be seen as one integrated part of the PortForward overall concept, there are several interdependencies between the deliverable D6.1, which is presented in this document, and other activities and deliverables of the PortForward project. The following figure gives an overview of the most relevant interdependencies.

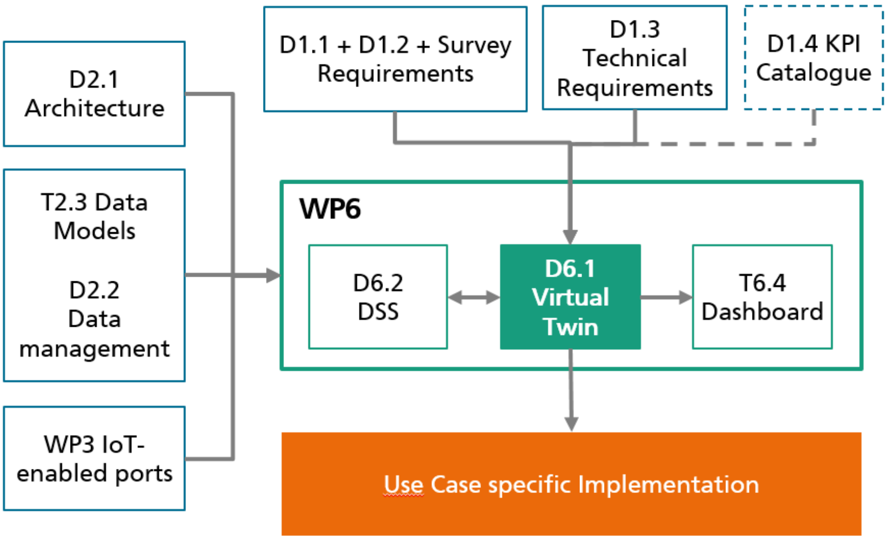

Figure 1: Interdependencies of D6.1

In general, the research results presented in the deliverables from D1.1 – D1.4 provide the basis of the Virtual Twin concept. In particular the descriptions of D1.2 and D1.3 deliver general requirements for a use case-specific concept of the Virtual Twin solution. The KPI definitions worked out in D1.4 are particularly relevant for the development of decision support solution DSS. Moreover, the KPI definitions will be partially respected in the parametrization of the component models of the Virtual Twin.

The description of the PortForward architecture, which is presented in deliverable D2.1, defines the framework for the implementation of the Virtual Twin solution. The basic restrictions, which can be derived from D2.1, have to be considered in the conceptual work on the Virtual Twin. The concepts of the component models and the integrated system model of the Virtual Twin must be transferred to

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appropriate concepts of data management, aligned to deliverable D2.2. The deliverables and results of WP3 ensure the availability of real time data from sensors and from distributed data sources for the Virtual Twin.

PortForward deliverables and activities with most relevant interdependencies with D6.1 are listed here below:

D1.1 Harmonized user needs and goals
D1.2 Use case analysis
D1.3 Technical requirements specification
D1.4 KPI catalogue
D2.1 PortForward architecture definition and analysis for standardization on ports
D2.2 Data management and security on PortForward architecture
T2.3 Interoperability and data modelling
D6.2 DSS concept and indicator description

1.5 The Virtual Twin in the PortForward framework architecture

This section describes how the Virtual Twin will be integrated into the overall PortForward architecture. For the discussion of the overall project architecture, please refer to the forthcoming D2.1, which will describe the PortForward framework through a holistic approach.

Through a 3D rendered model of the port area, the Virtual Port Twin provides an ergonomic interface to the operators and port administration to fulfil the relevant working tasks in an efficient way. The working tasks are mainly related to the operational issues of the port. Because of this, the 3D rendered model gives a real time view on the real physical objects while the physical objects, like vessels, vehicles or containers, continually send data to update their virtual representations in the 3D model. The general structure of the infrastructural environment, which is necessary to implement the idea of the PortForward Twin, is shown in the figure here below.

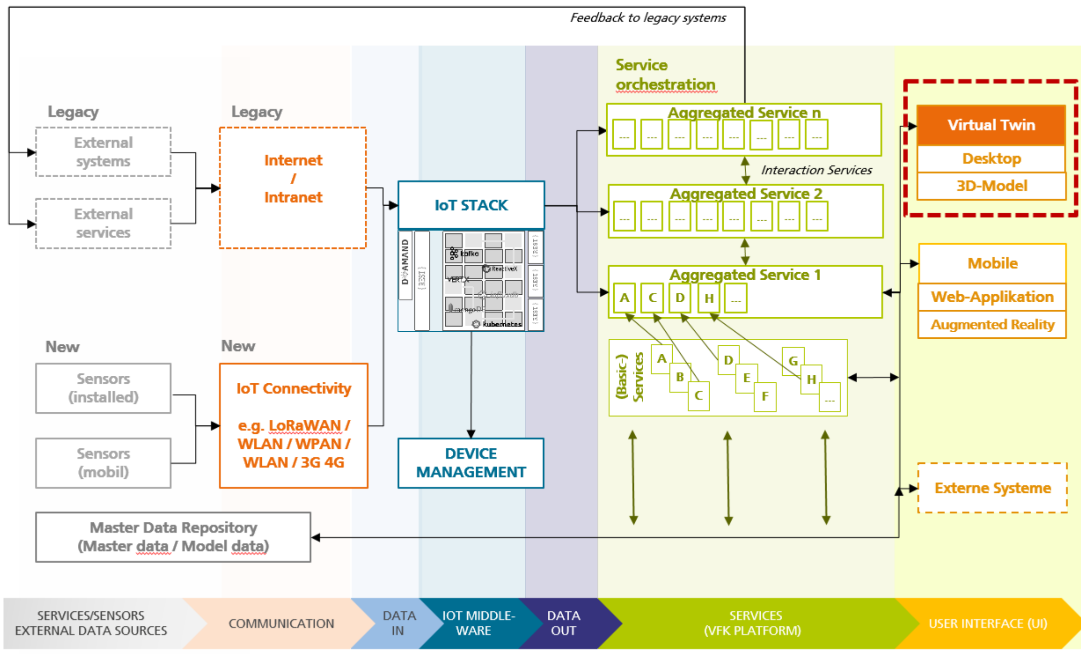

Figure 2: The Virtual Twin embedded in the PortForward framework

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From the point of view of the end users, the Virtual Twin can be recognized as a high-performant user interface (UI) using a 3D model. This solution provides a very efficient access to the port's relevant information in real time as well as efficient access to relevant planning and operating features of the PortForward framework. Moreover as described in Section 4, the model aspect of the Virtual Twin contains comprehensive structural and logical aspects, which are essential in the concept of the Virtual Twin.

The concept of the Virtual Twin in the PortForward project is specifically orientated to the requirements and working tasks that are associated with a certain situation in the port. The next section gives an overview about the present state existing in the different ports that are part of the PortForward consortium.

2 Present state in the ports – Virtual Twin solutions

This section describes how Virtual Twin concepts and Virtual applications are employed or can be employed in ports – including a brief overview on existing solutions over the ports of the consortium.

In order to get an actual and realistic view about the present state in the ports, a comprehensive survey was carried out. The results of this survey are summarized in the following tables.

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Table 1: Present state of the ports in terms of Virtual Twin solutions – Port of Vigo and Ports of Livorno, Piombino, Portoferraio

1	Name of the Port	Port of Vigo	Ports of Livorno, Piombino, Portoferraio
2	Virtual Twin solution, 3D model or digital process model in use	No Virtual Twin solution in use, 2D-framework (GIS and AIS) “Posidonia” is in use	MONI.C.A. - real-time 3D monitoring and control platform.
3	Short description about your existing or planned Virtual Twin	Posidonia (2D-GIS and AIS): - Single environment for all areas of the port - Integral management of port services - Automatic calculation of the different port fees and charges - It improves port automation and generates events for the full monitoring of the port management	MONI.C.A. manages the flow and aggregation of hetero-geneous data into events. It supports both Machine-to-Machine and Human-to-Machine processes. It enables to measure variables and events of interest for the whole Port System (boarding operations, meteoro-logical data, environmental sensors, surveillance, info-mobility, etc.).
4	Working tasks, which are supported using the Virtual Twin at the port	Managing tasks: - Port Calls, fishing unloading operations, vessel location and berth planning, sport boats, Port public domain, real time vessel location and berth planning port services , Invoicing and settlement Operation tasks (next services): - detecting multiple events in the life cycle of a vessel in port and allows the automation of actions and assists a port operator in controlling the vessel’s visit to the port	The principal tasks managed by MONI.C.A. Platform are: - Boarding operations - Meteorological data - Environmental Sensors - Surveillance - Infomobility.
5	stakeholders (internal / external) using the Virtual Twin solution.	Posidonia is used by staff member of Port Authority of Vigo.	The Platform is used principally internally for monitoring and control purpose. It is used marginally by the Harbour Pilots.
6	Data handled in the Virtual Twin solution	Posidonia (2D-GIS and AIS): - AIS, Fishing, DUE	- Weather sensors data - Air pollution sensors data - AIS data - Radar data - Surveillance Cameras images - Ship List

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			- OCR data - RFID data - Shipped Goods; etc.
7	Working spaces / user interfaces, which give access to the virtual twin	Posidonia (GIS and AIS): - desktop application on a classical office workspace	There is two kind of user interfaces deployed: - A 3D real-time application, in which the operators can monitor the Port - A web application, in which is deployed the statistics module and digital timetables
8	Short outlook on any developments and extensions of the Virtual Twin, which are planned	Platform SMARTVIPORT - is under development: 2017 – 2022 - 3D model of port facilities and infrastructures - basic services	It's planned to collect the bathymetry data and share it with the Harbor Pilots. Moreover, extend the infomobility services in the other ports managed by The Port Network Authority.
9	Working tasks can be supported by Virtual Twin solutions in your opinion	3D visualization in real-time of port infrastructures, store goods, activities, including detailed data facts - Tracking freight in real time - Enhanced managing of spatial infrastructures; considering Building Information Modelling BIM	In our environment, the utility of Virtual Twin could have a big impact to support human monitoring and control operations.
10	Relevant main features for a Virtual Twin in PortForward	Dynamic showing information in real time	Ship and Goods real-time monitoring for support the operations of Harbour Pilots and Customs Officers.
11	Further remarks	Port of Vigo is developing SmartViport (2015-2022) and we are at the beginning of the BIM modelling of port infrastructures. A virtual twin should consider the compatibility with these tools.	None

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Table 2 Present state of the ports in terms of Virtual Twin solutions – Port of Kristiansand and port of Naples

1	Name of the port	Port of Kristiansand	Port of Naples
2	Virtual Twin solution, 3D model or digital process model in use	No Virtual Twin solution in use	DIVAONLINE - 3D online platform
3	Short description about your existing or planned Virtual Twin	-	DIVAONLINE provides a full-scale Cruise Terminal representation that shows: - the ships docked and their position; - the inbound and outbound cruise traffic (also showing the scheduled timings); - the length of the ships; - the name of the ships and the piers-related number where they are docked.
4	Working tasks, which are supported using the Virtual Twin at the port	-	- Daily monitoring an planning of the cruise terminals - Elaboration of port strategical plan - Investment planning - Concession monitoring and planning
5	Stakeholders (internal / external) using the Virtual Twin solution.	-	DIVAONLINE is used by staff member of Port Authority of Naples.
6	Data handled in the Virtual Twin solution	-	The system does not provide real-time data, but daily refreshed ones, and also it allows to check the scheduled calls of the upcoming nine days. Through the system, it is possible to consult further information, such as:

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			- *Technical data*: length, height and depth for pier - *Fares:* rights charged to inbound/outbound/in transit passengers, ship docking etc.
7	Working spaces / user interfaces, which give access to the virtual twin	-	
8	Short outlook on any developments and extensions of the Virtual Twin, which are planned	-	The Port Authority has planned works for over 200 million euros: the most important, not only from the economic point of view but especially from the infrastructural one is the New Terminal of Levante. The works, once completed, will equip the port of Naples with a terminal of 250,000 square meters and a front dock of 672 m. for the docking of new generation container ships.
9	Working tasks can be supported by Virtual Twin solutions in your opinion	- Management of the terminals: Tracking of goods using GPS would help us keep track of what is where at which area. This again will help the port to get a better understanding of how the operation at our port flows. - A layout of our berths will help us better plan traffic and could help us describe our berths to customers. Easy access to solutions above will help all operators at the port to plan ahead.	See remarks in point 4.
10	Relevant main features for a Virtual Twin in PortForward	Tracking of goods and assets will help us plan better. The same will be valid for traffic planning.	The port of Naples is a multipurpose one and the there are few public spaces. The port face a number of critical issues related to the management of those spaces. Some of these are related to the following: - Seaside spaces, Landside spaces, In-port traffic flows.
11	Further remarks	None	None

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Table 3: Present state of the ports in terms of Virtual Twin solutions – Port of Magdeburg

1	Name of the port	Port of Magdeburg
2	Virtual Twin solution, 3D model or digital process model in use	VRS-platform - 3D platform for development and planning
3	Short description about your existing or planned Virtual Twin	The current Virtual Twin of the Port of Magdeburg provides comprehensive information about the port area and the surrounding industrial and urban areas. The photorealistic 3D model is true to scale and allows an interactive information retrieval about the infrastructures, facilities and capabilities of goods handling and storage. The System is not connected to external sensors and provides no real time data about operational processes.
4	Working tasks, supported by using the Virtual Twin	Currently the following working tasks are supported by the Virtual Twin: - Locational and land-use planning on a strategic level, Order planning, Marketing and order acquisition.
5	stakeholders (internal / external) using the Virtual Twin solution.	The Virtual Twin Solution is used by the following staff members of the port administration: - Managing directors, Staff members for locational and land-use planning, Staff members of marketing and order acquisition.
6	Data handled in the Virtual Twin solution	Geographical base data from the federal state of Saxony-Anhalt were imported to generate the spatial structures: - Digital Terrain Model DTM20; Digital orthophotos DOP 20 ; 3D Buildings LoD2 Specific background data from the port management systems (e.g. capacities, possibilities of use, quality standards).
7	Working spaces / user interfaces, which give access to the virtual twin	The Virtual Twin solution is running as a desktop application on a classical office workspace environment. If the Virtual Twin is used for marketing and order acquisition, large-scale displays with stereoscopic 3D View come into use. Yet, there are no interactively usable mobile solutions for the Virtual Twin of the Port of Magdeburg.
8	Short outlook on any developments and extensions of the Virtual Twin, which are planned	The system will be qualified to support operational processes in real time. essential extensions in the spatial model and a new logistic model are needed. The Virtual Twin of the Port of Magdeburg will be transformed to a location-wide system, which is cross-linked with external sensors in the port area using middleware capacities and cloud services. New interactive functions and visualization techniques in the Virtual Twin are foreseen as well.

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9	Working tasks can be supported by Virtual Twin solutions in your opinion	Dynamic management of storage locations in multi-purpose terminal can be supports by Virtual Twin solution. When goods are stored in changing locations, the handling of the goods needs to be tracked (e.g. by D-GPS). The tracking of assets, equipment and freight in real time promises a significant new data quality for a more efficient organization of the port processes.
10	Relevant main features for a Virtual Twin in PortForward	The aim in PortForward must be a Virtual Twin solution, which can support, monitor and manage operative processes in the port of Magdeburg. The key aspects of this transformation process are already described under point 8.
11	Further remarks	The Port of Magdeburg wants to qualify the existing Virtual Twin, which is mostly a static representation of the port area, to a dynamic Virtual Twin. In the future operational processes in the port should be supported in real time.

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3 Use case-related requirements to the Virtual Twin

The required characteristics of the Virtual Twin are use cases and workings tasks-specific. From the analysis of the data collected in Section 2, it is possible to identify target applications with high priority, which a virtual twin solution can provide support for. In the following, this basis is made more concrete for further conception of the virtual twin.

"Smart solutions for logistics" was identified as one of the high priority cross-site-relevant applications. Logistics processes in port locations with heterogeneous cargo handling and storage implies a specific complexity. The Magdeburg port is an example of this type of ports. Because of this, the Virtual Twin concept will be developed taking into account the Magdeburg use cause if specific details and issues must be described.

For the Magdeburg port, the use case "Dynamic Storage Monitoring" was already described in D1.3 in a general way. This use case is chosen as the primary use case, which is relevant for the Virtual Twin development. In the following additional specifications are derived. These are necessary to develop the concept of the Virtual Twin further.

3.1 Basic spatial structures in the Port of Magdeburg

This section gives a systematic description about the relevant structures, existing in the port area and of their organization. The port of Magdeburg has 6 different terminals. The figure here below gives an overview.

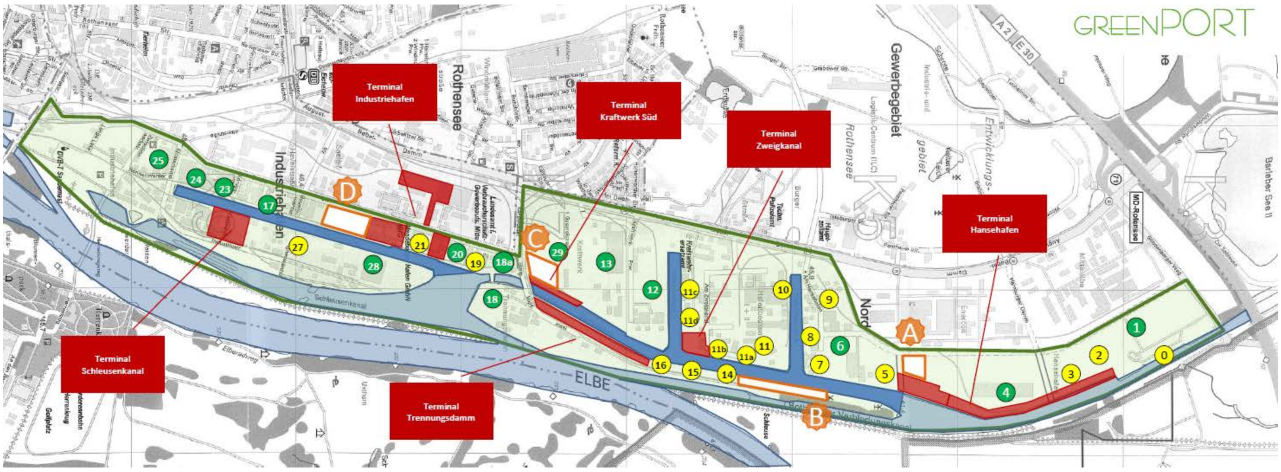

Figure 3: General overview about the spatial structure in the port of Magdeburg

These terminal areas are subdivided dynamically into storage areas of different sizes for the handling or storage of the orders coming from the customers of the port. A fixed division to defined storage areas is not possible due to the diversity of the goods, handled in the multi-purpose terminals. The type and the amount of goods that can be handled or stored in the terminals are determined in Germany by the so-called BImSchG approvals, which base on the Federal Immission Control Act (Bundes-Immissionsschutzgesetz - BImSchG).

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3.2 Basic logistic processes

For the use case of the dynamic storage monitoring the process environment and the processes of the multi-purpose Hanse-Terminal need to be represented in the Virtual Twin. The figure here below gives a general view of the Hanse-Terminal.

Figure 4: Multi-purpose Hanse-Terminal of the Port of Magdeburg

The multi-modal Hanse-Terminal is used to handle and store different types of general cargo and project cargo, including heavy-duty cargo and dangerous goods. Besides the spatial structure of the terminal (including storage areas for heavy duty and dangerous goods), the following elements are relevant for the logistics model:

- Processes
  - General handling between transport modes (water, road, rail)
  - Storage of general cargo
  - Storage of special cargo (heavy duty, dangerous goods)
  - Internal transport when cargo needs to be relocated
- Assets (port equipment for handling operations)
  - Crane (covering approx. ¾ of the terminal)
  - 2 Reachstackers for container handling
  - 1 Forklift for handling of pallets
  - Heavy duty auto-cranes (on request – from external service providers)
- Typical types of handled cargo
  - ISO-Containers
  - Pallets
  - Big machine parts (mainly components for wind turbines)
  - Special big sized / heavy duty project cargo
  - Dangerous goods (e.g. in containers)

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4 Integrated system model of the Port – in Concept

The integrated system model of the port is the first essential component in the concept of the Virtual Twin. It describes structures and processes of the relevant area, which are mapped by the virtual twin.

Specification and scope of the integrated system model is use case specific and includes all disciplines relevant for the use case. For the application of Magdeburg port these are spatial management and logistics.

The use cases, which the virtual twin will support, require a complete overview over the port system, bringing together spatial and logistical aspects. For this purpose, an integrated system model must be developed. First, the required component model of spatial planning and logistics must be described. After this, the component models must be brought together to an integrated space logistics model of the location.

The modelling of the integrated system model takes place in a 5-step process, which is shown schematically in Figure 5.

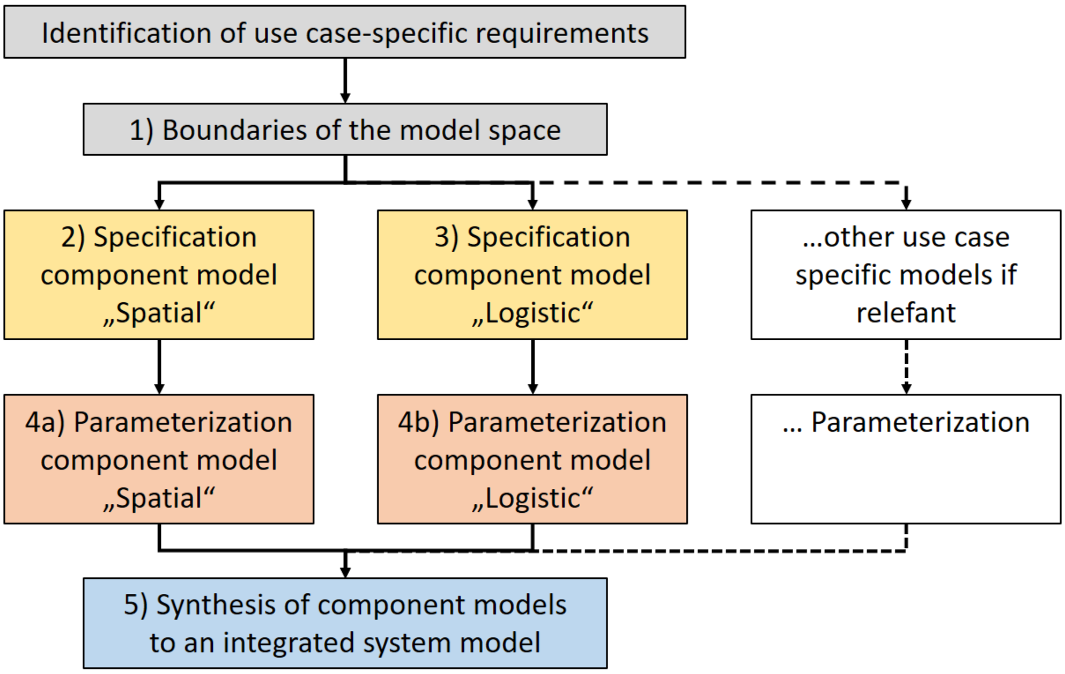

Figure 5: Generic procedure for development of an integrated system model for port areas

As shown in Figure 5, this method is generic. If different use cases require to include other specific component models, the working process can be extended easily.

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4.1 Specification component model „Spatial“

The spatial model represents the spatial structure of the port in a system view. The following system components are described here:

- System environment, boundaries and interfaces,
- Subsystems (terminals and storage spaces),
- System elements (spatial squares).

The component model “space” is developed in a hierarchical model view (Ropohl, 2012). From the point of view of the spatial planning, the port area can be divided in various hierarchical levels, see Figure 6.

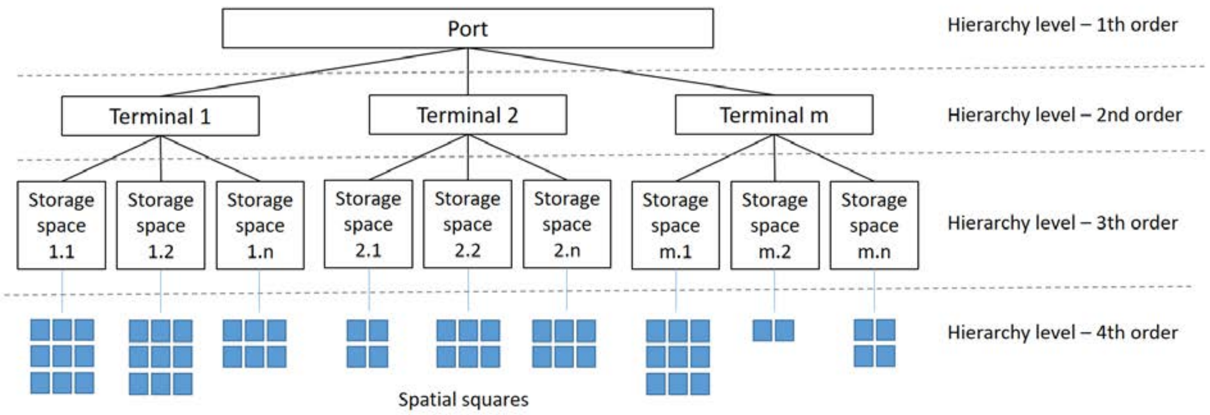

Figure 6: Hierarchical structuring of space in the port area

4.1.1 System boundaries and environment

From the point of view of the spatial planning, the system boundaries of the location are clearly defined by the scope of the “development plan from the public authorities”. The communal space is the system environment of the port.

4.1.2 System interfaces / in- and outputs

From the point of view of spatial planning, the port system is as a first step a closed system whose boundaries and initial spatial resources (storage spaces) are clearly defined by the urban development planning. Interfaces or system input or output to change system status on the basis of these initial spatial resources are not existing.

4.1.3 Subsystem: Terminal

The port space is subdivided in separate terminals. Theses areas are spatially delineated by the “development plan from the public authorities” and have use-specific restrictions, especially in terms

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of handling and storage. Terminals form storage spaces with individual specifics and in this way they are a kind of subsystem in the port.

4.1.4 Subsystem: Storage space

A storage space is a defined space to store or handle cargos in the terminal area.

Because heterogeneous goods in very different dimensions occupy storage spaces, they cannot be defined with permanently fixed area sizes. In contrast to terminal areas they are defined dynamically. For this purpose, a virtual square net is laid over the terminal area, see the following section.

4.1.5 System element: Spatial square

In the development of the spatial model, the spatial squares are the smallest planning unit. They have a square shape and a defined length and width, which can vary depending on the size of the terminal and that of the goods to be stored. For the use case of Magdeburg port, a size of 2m x 2m is chosen.

These spatial squares are used by the responsible employees depending on the availability of free spaces and necessity to form storage spaces.

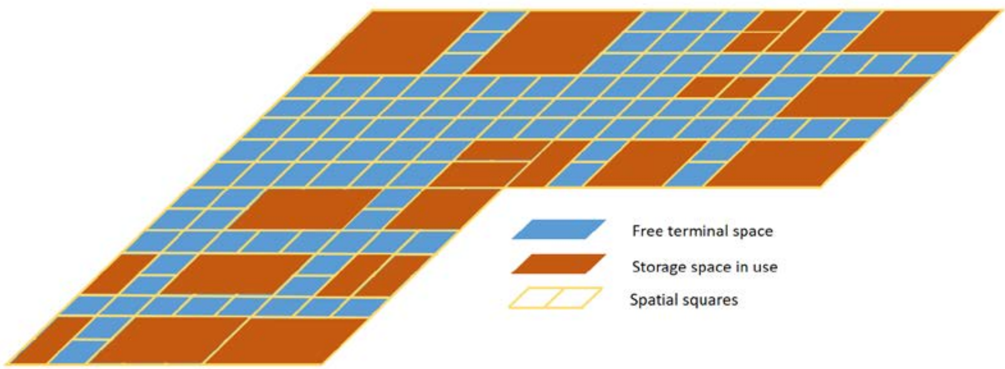

Figure 7: Schematic representation of a terminal with storage spaces and spatial squares

The presented spatial structuring of the port system creates the necessary flexibility in space management for the Virtual Twin, as required by the “dynamic storage monitoring”.

4.2 Specification component model „Logistic“

Due to the logistic model, the various relevant logistic elements are aggregated to perform port procedures. Besides the spatial structure, whose specific characteristics are described by the spatial model, the logistic model includes following elements:

- Types of goods and cargo
  - Piece goods
  - Bulk goods
- Port internal equipment

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  - Storage equipment
  - Handling equipment (crane, reach stacker, ...)
- Means of transport
  - Water
  - Road
  - Rail

The logistics elements are structured hierarchically according to following figure, analogously to the spatial model.

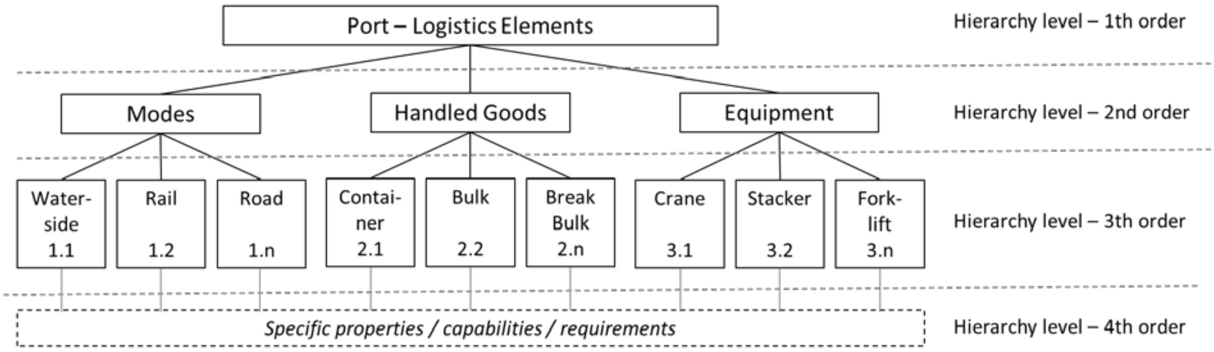

Figure 8: Hierarchic structuring of logistics elements

For the logistic elements a relation exists to the spatial model through the specific characteristics of the respective port areas. Depending on the logistical target process (transportation internal /transportation external / handling / storage / commissioning / other handling as package, declare etc.) different characteristics of the respective logistics element and the respective port area are relevant. This becomes clear using the following example:

➔ Target process: **Storage**

- **Characteristic of storage space**: available space / max. load of space/ media supply / classification of Federal Emission Control / dry and/or cooling/ accessibility by transport mode/ availability of handling equipment / …
- **Characteristics of stored goods**: Type of good / volume + dimensions / weight / specific requirements (dangerous goods/ chilled cargo / …) / storage period + call-off terms/ …
- **Characteristics of equipment**: max. lifting capacity / handling of goods / …
- **Characteristics of means of transport**: not relevant

For each type of process, an individual set of characteristics is relevant. The whole logistic system must be optimized in such way that bottleneck resources, i.e. those resources, which meet very specific requirements (e.g. spaces for dangerous goods), are used by these goods as priority.

In principle, the logistic model can be expanded adding the element of the employees with the pertinent required qualifications.

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4.3 Parametrization of component models "Spatial" and "Logistic"

Using the parameters of the system elements, e.g. size and usability of spatial square, the state of the system of the port can be described. In further modelling, parameters must meet the following basic requirements:

- Quantifiability (measurability or countability),
- Availability (simple recording, no intervention into the operation of the port),
- Relation to system (clear allocation to subsystems, part systems or system element),
- Parameters which are not directly quantifiable due to their characteristics should be preferably classified qualitatively [0...1] and that way should be convertible into a quantifiable form.

Planning parameters are treated as specific input variables to determine the existing situation and the target definition in the functions of the decision support system, see D6.2 for further discussion of the decision support system[1].

4.3.1 Spatial parameters

The following table gives an overview of the method relevant spatial parameters. A distinction is made between area-specific spatial parameter, which intrinsic characteristics specify the spatial resources, and use-specific spatial parameters, which arise from the use of spatial resources.

Table 4: Area and use-specific parameters to specify the component model "Spatial"

No.	Parameter	Symbol	Unit	Data source
Area-specific spatial parameters				
S1	Space	A	m^2	Land register, data files of Port Authority
S2	Occupancy rate	AG	%	Data files of Port Authority
S3	Utilization potential	P	[ ]	IED / Federal Emission Control Act
S4	Load	BK	$\frac{t}{m^2}$	Data files of Port Authority
S5	Connection to transport modes	VT	[ ]	Data files of Port Authority

[1] Please note that D6.2 is marked as confidential and might not be accessible through public sources. Please contact the coordinator for a personal clearance of the document.

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Use-specific spatial parameters				
S6	Type of use	NA	[ ]	IED / Federal Emission Control Act
S7	Duration of use	ND	[d]	Data files of Port Authority
S8	Accessibility	ZG	$\frac{TEUR}{a}$	Data files of Port Authority
S9	Emissions	EM	[0 ... 1]	Measurement by Port Authority
S10	Income	E	$[\frac{TEUR}{m^2\ a}]$	Data files of Port Authority
S11	Costs	K	$[\frac{TEUR}{m^2\ a}]$	Data files of Port Authority
S12	…			
…	…			
Relevant KPIs from KPI catalogue (from D1.4[2] without further specifications)				
K1	Average size of concessions		[ ]	
K2	Saturation degree of access infrastructure			
K3	Space efficiency			
K4	Ground flows			
K5	Areas return per business			

[2] Please note that D1.4 is marked as confidential and might not be accessible through public sources. Please contact the coordinator for a personal clearance of the document.

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In the following the area and use-specific spatial parameters are described in more detail.

The space A $[m^2]$ describes the size of the spatial resource (terminal, storage space etc.).

The occupancy rate AG [%] describes to what extent a spatial resource is used or which utilisation potential there is.

The load BK $[\frac{t}{m^2}]$ of the ground describes which maximum load can be handled or stored in a specific area.

The utilization potential P[ ] of a space derives from the Industrial Emissions Directive 2010/75/EU, IED and the resulting national laws. The IED describes regulations about approval, operation, monitoring and decommissioning of industrial plants in the European Union. It is based on a proposal of the European Commission from 2007 and was adopted by the European Council and European Parliament in 2010.

The IED was implemented at national level by corresponding laws. For the areas of ports, especially the Federal Emission Control Act BImSchG is relevant in Germany. It regulates which type of goods can be stored and handled on the respective areas.

The connection to transport modes VT [ ] has decisive influence on the space potential in the trimodal logistics area (water, rail, road) and which handling or storage orders can be performed on this area.

The type of use NA [ ] arises from federal emission control of the order, which is realized in that area. A distinction is made between handling and storage.

The duration of use ND [d] describes the expected duration of space utilisation.

Emissions EM [0 ... 1] describes the amount of emissions from space utilization.

The income E $[\frac{TEUR}{m^2\,a}]$ describes revenue, which are gained by space utilizations per year.

The costs K $[\frac{TEUR}{m^2\,a}]$ describe the financial expenses, which result from management of area.

4.3.2 Logistic Parameters

The following table provides an overview of the method-relevant parameters of various logistics elements. Here, a distinction is made between parameters for the respective elements of the logistics goods, resources and means of transport.

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Table 5: Parameters to specify the component model "Logistics"

No.	Parameter	Symbol	Unit	Data source
Cargo-specific parameters				
G1	Kind of good (KN-Code)[3]	KN	[ ]	Shipper
G2	Weight	w	kg	Shipper
G3	Dimensions	LWH	$cm * cm * cm$	Shipper
G4	Packaging (Container, Pallets, …)	PK	[ ]	Shipper
G5	Dangerous Goods identification (HazMat)	HZ	[ ]	Shipper
G6	Storage requirements (dry, cool, …)	SR	[ ]	Shipper
G7	Critical Dates (e.g. store until, …)	DT	dd/mm/yyyy	Shipper
G8	Stacking capability	SC	[ ]	Shipper
G9	Item identification	Gid	[ ]	Shipper / Operator
G10	Item location	Gloc	Lat / Lon	Shipper / Operator
G11	…			
…				
Operating equipment-specific parameters				
A1	Asset utilization	AU	%	Operator / Port Authority
A2	Operating hours	OH	h	Operator / Port Authority
A3	Next MRO date	MRO	dd/mm/yyyy	Operator / Port Authority

[3] Based on the EU Regulation 2018/1602 for the Combined Nomenclature

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A4	Handling of… (Containers, Palets, …)	HAN	[ ]	Operator / Port Authority
A5	Max. lift weight	mLW	kg	Operator / Port Authority
A6	Max. stacking height	mSH	[ ]	Operator / Port Authority
A7	Asset identification	Aid	[ ]	Operator / Port Authority
A8	Asset location	Aloc	Lat / Lon	Operator / Port Authority
A9	…			
…				
transport vehicles-specific parameters				
T1	Vehicle / ship utilization	VU / SU	%	Operator / Carrier
T2	Max. load capacity	mLC	kg	Operator / Carrier
T3	Estimated time of arrival	ETA	dd/mm/yyyy hh:mm	Operator / Carrier
T4	Estimated time of departure	ETD	dd/mm/yyyy hh:mm	Operator / Carrier
T5	Average terminal time	ATT	hh:mm	Operator
T6	Vehicle / Ship identification	Vid / Sid	[ ]	Operator / Carrier
T7	Vehicle / Ship location	Vloc / Sloc	Lat / Lon	Operator / Carrier
T8	…			
…				
Relevant KPIs from KPI catalogue (from D1.4[4] without further specifications)				
K6	Average load per ship			
K7	Traffic distribution			

[4] Please note that D1.4 is marked as confidential and might not be accessible through public sources. Please contact the coordinator for a personal clearance of the document.

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…				

The logistic parameters are self-descriptive. They can also be extended in the further project work, if necessary.

4.4 Integrated system model of the port – synthesis

The hierarchically structured spatial model, see Figure 6, is developed vertically. The spatial squares of the spatial model represent the total spatial resources of the location. The operator can merge dynamic storage areas (third hierarchy level of the spatial model) by defining a set of spatial squares. These storage areas can then be occupied by defined logistics elements (third hierarchy of the logistics model – see Figure 8). At this level, a first synthesis of the space and logistics model to an integrated overall model can be performed.

These spatial and logistic planning parameters can be projected from the third level in the higher hierarchy levels using summation methods, so a holistic descriptive model view can be aggregated in all hierarchy levels of the integrated system model of the port.

5 Virtual interactive Port model – Working in VR

Virtual interactive technologies are establishing new forms of interdisciplinary working in spatial planning and managing logistic processes, making it possible to map and convey the complexity of working tasks in the use case appropriately (Höpfner, Mencke, Lombardi, Franke, & Komarnicki, 2017).

5.1 VR model data

5.1.1 VR model data and its data input sources

The VR spatial model reproduces the port's structure. Different input data sources and 3D modelling methods can be used to create a VR spatial model. The 3D geometries can be organised in component groups of:

- digital terrain models (DTM),
- buildings and structures,
- vegetation, and
- secondary objects (e.g. objects of logistics and urban spaces).

Different methods for generating terrain models exist, which are suited to support the case study explored here. The terrain model of Industrie- und Logistikcentrum Magdeburg Rothensee ILC, Germany (which is located beside the port of Magdeburg) in Figure 9 was generated in a semi-automated method. The data input for this were:

- a complete digital site plan,
- relevant elevation data from a digital terrain model DTM, and
- 3D buildings form the land surveying office of the federal state Saxony-Anhalt
- synthetic textures from a texture library (orthophotos were used in peripheral areas).

The level of automation in modelling depends on the digital 2D site plan's data hygiene and quality.

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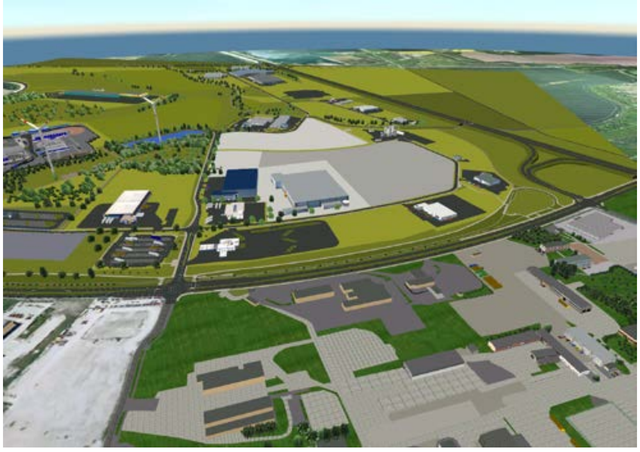

Figure 9: Bird's –eye view virtual model of the industrial park ILC Rothensee in Magdeburg

Buildings are represented by virtual 3D models. Virtual 3D models of buildings and structures can be differentiated by level of abstraction. The City GML standard distinguishes four levels of detail (LoD) for 3D buildings, see figure below.

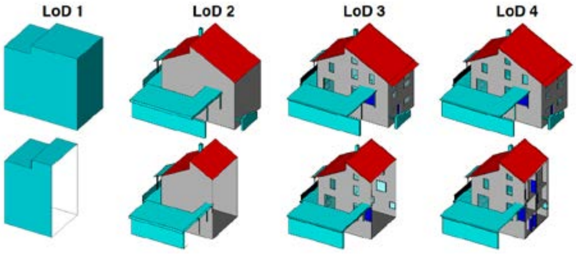

Figure 10: LoD1- LoD4 of CityGML

The proprietary industry standard Blom3D™ distinguishes four levels of detail. BlomLOD4™ features facade geometries, basic roof shapes and photorealistic texturing, extracted from oblique aerial photographs, see Figure 11.

Figure 11: BlomLOD4™ 3D building with photorealistic textures

Virtual building models that reproduce a building shell's geometry and photorealistic surface are suited for the Virtual Twin. This corresponds to a BlomLOD4™ or a texturized CityGML LoD 2.

Vegetation can be integrated in the model area automatically by using digital cadastral maps or manually by using the virtual reality environment's interactive functions. Information on the existing tree population can be important for evaluating planned capital expenditures and especially for visibility of future buildings in the surrounding urban area.

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Secondary objects (e.g. logistic objects) can serve as model-immanent indicators spatial uses of buildings or areas. This facilitates access to planning area, thus increasing the quality of the VR model.

Relevant specifications are assigned to the ports spatial elements visualized by scale 3D geometries to complete the VR model. The elements perceptible in VR model are rendered from:

- a unique object ID,
- hierarchical context,
- textured 3D geometry,
- coordinate values, and
- parameters specific to the spatial element.

These steps deliver a 3D VR spatial model that constitutes the basis for integrating other specific planning models such as an energy model.

5.1.2 Appropriate approaches of data management and data storage

One main part of the data management is storing the data. Different strategies of data storage for the Port Forward Virtual Twin were evaluated and two different ways have been identified to come to a suitable solution:

- File system
    - Standardized formats
    - Own or proprietary formats
- Databases
    - Relational Database
    - NoSQL Database

Another main aspect of data management is to describe the requirements on the handling of the data or the requirements which reveal of the data itself. Based on the requirements the selection of the appropriate storage concepts shall be done. The following specifics and requirements has been identified as key criteria to define an appropriate data storage concept:

- amount and frequency of writing and reading
- availability
- frequency of changes
- exchange with other systems
- amount
- size of data packets / entities
- structure (simple, hierarchical)

5.1.3 Appropriate approaches of interface implementation

Accessing or exchanging data can be done based on various concepts or technologies. Either, data can be requested from a target system at a source system or data can be pushed from a source system to a target system. The combination of both is based on the publish/subscribe approach which means that whenever new data are created or data are changed these data are sent to every system that subscribed for receiving.

This document focuses on the description of data exchange between different systems which means that information exchange is based on data (data storage like file system or database) or software

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interfaces (data exchange between software, applications or operating systems). A common approach to exchange data between different systems is based on the use of Web Services (RPC, SOAP, REST). Web Services are mainly used for requesting needed data (pull) or sending new or updated data (push).

For the event driven approach by forwarding data when their creation or change occurs it is possible to implement interfaces based on publish/subscribe with the use of the standards MQTT (Message Queuing Telemetry Transport, an open message protocol for Machine-to-Machine communication) or AMQP (Advanced Message Queuing Protocol (AMQP), an open standard application layer protocol for message-oriented middleware). The main difference between both protocols are the possible options in delivering messages. AMQP offers the possibility to queue messages while this is not possible when using MQTT.

Suitable basic concepts of data handling have been identified. They will specified in more detail and adapted to the holistic Port Forward solution presented in the corresponding deliverables of WP3.

5.2 Visualization and interaction concept

The visualization and interaction concept takes systematically advantage of the capabilities mentioned must be developed. The VR system "VRS platform" is specified as the basic software system that will render the virtual twin in the user front end. The system provides basic visualization and interaction techniques, which can be adapted and extended to the specific requirements of the Port Forward Virtual Twin. The following figure gives an idea about this platform.

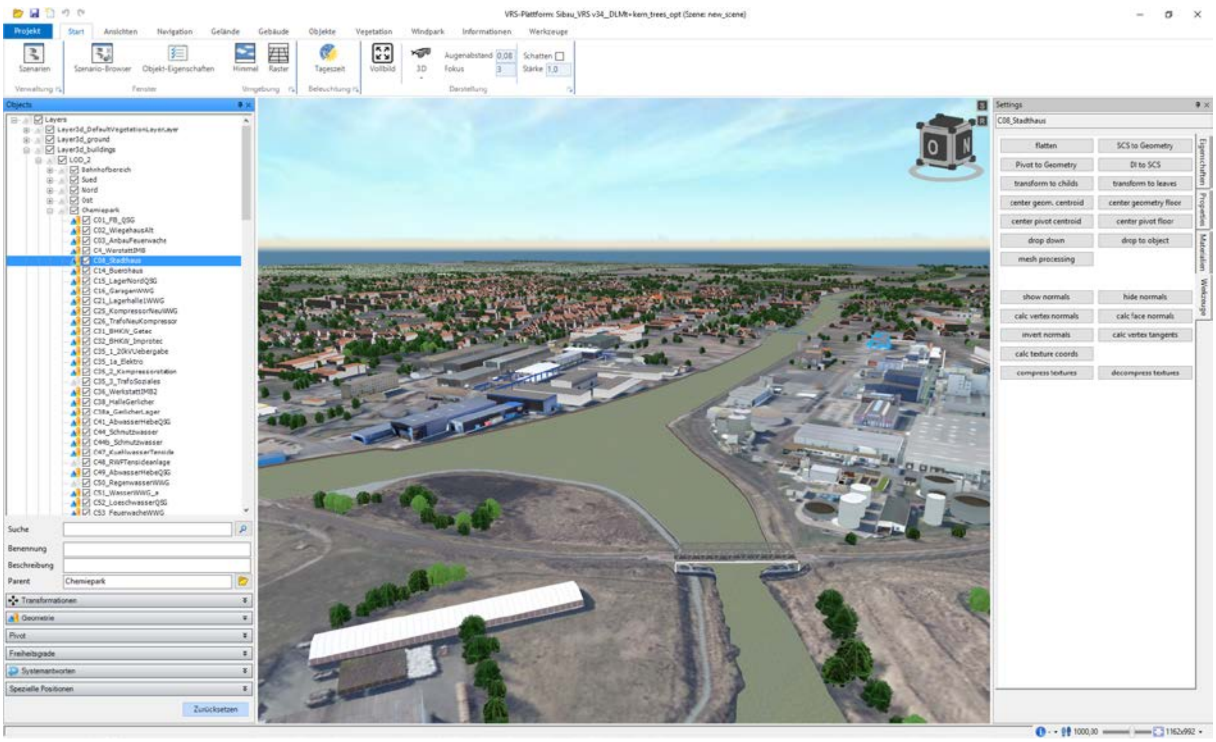

Figure 12: VRS-platform, rendering a Virtual Twin of an urban area

The Virtual Twin has to be specified with its implemented visualization and interaction functionalities based on the work tasks addressed in the use case. Essentially, they are:

- Representation of the ports' current status

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- Integrated overview about the local site
- Details of the ports' individual spatial and logistic elements
- Details about the capacities in the port's storage spaces

- Planning and working functions
  - Current target plan
  - Interactive planning tools a 3D object library
  - Access to analysis and assessment functions of the DSS (D6.2)
  - Access to the relevant functions of the dashboard
- Managing functionalities
  - Actual model with real life status of the port
  - Port history representing status of the port in the past
  - Variation models giving different alternatives of future port developments

5.2.1 Visualization techniques

The photorealistic 3D model of the port is the central element of this visualization and interaction concept. Virtual models of existing architectural and engineering structures nowadays achieve a new level of realism. The port area can be analyzed and evaluated effectively in VR environments that correspond to the real onsite situation in detail. Use of additive, non-photorealistic rendering techniques to visualize imperceptible planning parameters in virtual reality enables combining plans from different disciplines in one virtual model area (Semmo A. "., 2016). Suitable visualization techniques in the planning context selected here, include:

- highlighting object surface shapes and object outlines (Lawonn, Gasteiger, & Preim, 2013), (Mower, 2015), (Rocha, Markus, & Celes, 2011)
- color-coding photorealistic models (e.g. visualizing land values) (Gang, Choi, Kim, & Choung, 2016)
- adding 3D elements (e.g. visualizing synergies among companies), and
- abstracting irrelevant areas of analysis (Semmo, Trapp, Kypriandis, & Döllner, 2012)

Thus, for example, the substitution of the photorealistic terrain surface by color coding can make the values of specific parameters in the port understandable to the end user in a very efficient way. Its specific features cause this non-photorealistic technique to reproduce values clearly but fuzzily. Effectiveness and efficiency in virtualization is maximized in combination with interactively selectable overlays, which deliver numerically exact values but lose some clarity when quantities of information are larger.

5.2.2 Interactions

Extensive interactions have to be provided to the users to complete the defined work tasks. Apart from standard free 3D navigation and standard information and parameter retrieval, such interactions involve monitoring, planning and modifications functionalities for the integrated spatial and logistic model. A suitable interaction concept makes the interactive functions available in a structured form. A central element of this concept, an interaction diagram specifies the virtual twin solution's range of interactions and functions. The structure of the interaction diagram is developed geared toward the work tasks defined at the outset of this sub-section, see the following figure.

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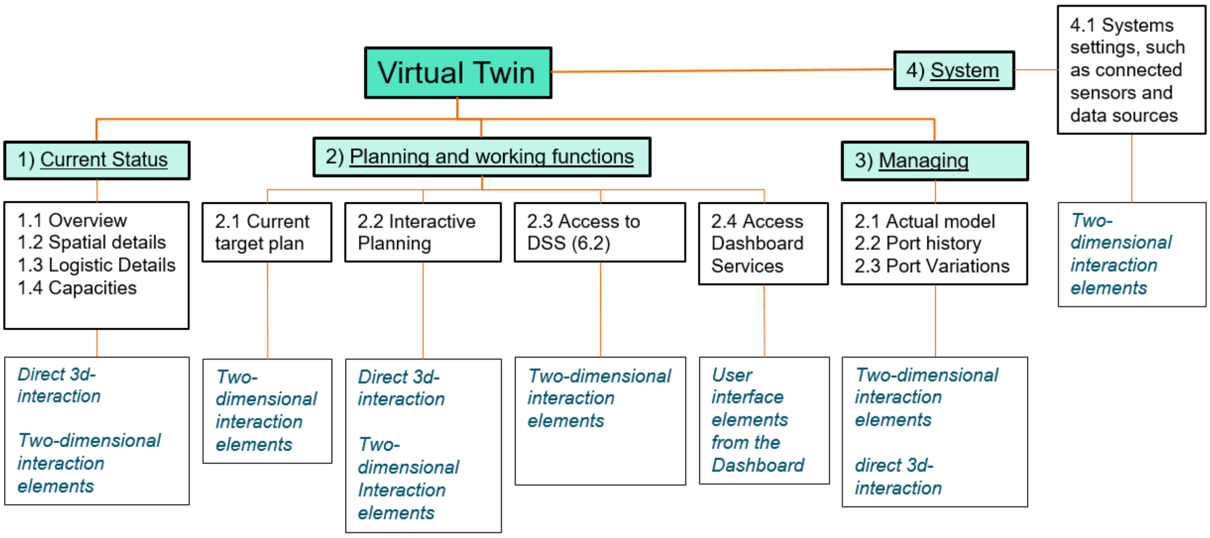

Figure 13: Interaction diagram of the Virtual Twin

Interactions for real-time work in the virtual 3D environment are foreseen for an implementation. Standard 2D interaction elements and embedded interaction elements from the dash board and the DSS, such a graphical UI-components will complete the range of interaction elements, so the complete set of interaction elements will be sufficient to complete the relevant work tasks.

5.3 Hardware front end to the Virtual Twin

Given recent hardware and software developments, hardware frond ends connected the Virtual Twin can have widely varying specifications. The most suitable hardware front end is use-case specific again. Because of the discussions with the intended end users of the “dynamic storage monitoring” the final solution is assumed to have been designed mainly for a local workstation.

Other hardware setups with high-performant specifics can be connected to the Virtual Twin. Significant higher costs have to be considered here. An example for such a hardware setup is the Virtual control room located at the Fraunhofer IFF, see the figure beside, or the Fraunhofer IFF’s VR laboratory Elbedome, see www.elbedome.de.

Figure 14: Virtual control room

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Furthermore mobile AR-front ends can be connected to the Virtual Twin and its data. The need for their implementation depends on the working processes and the user roles relevant in the use case. Detailed descriptions about implementations will be given with the documentation of the specific use cases (in deliverables D7.2 and D7.3). The figure beside shows an example.

Figure 15: AR-front end (Ubimax GmbH)

6 Conclusions

This deliverable gives a general overview about the Virtual Twin concept as well as a first description of a use case-specific type of a Virtual Twin. The use case refers to the Port of Magdeburg: “dynamic storage monitoring”.

After general explanations, which are important for a better understanding of this deliverable, a comprehensive survey about the present situations of the ports that are part of the PortForward consortium is given, focusing Virtual Twin solutions in use and in planning. Virtual Twin solutions, which are partially in use in the ports, are presented. Furthermore, in this survey relevant working tasks and use can be identified.

Based on this general approach the development of the Virtual Twin and fundamental components of a Virtual Twin are described. The integrated system model, which maps the structural and logical basis for the Virtual Twin is described as well as its virtual interactive components, which leads to new forms of interdisciplinary working in VR. Use case-specific features of a Virtual Twin are described referring to the use case of the port of Magdeburg.

At the current stage of the project, it is not possible to describe a concrete and fully detailed Virtual Twin solution. The detailed specifics about the implementations of the Virtual Twin need to be discussed further with the development and use case partners based on this initial concept. Thus, further descriptions about developments and implementations of Virtual Twin will be given with the documentation of the specific use cases (in deliverables D7.2 and D7.3) and in WP6’ D6.3.

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