OPTIMUM

OPTimised Industrial IoT and Distributed Control Platform
for Manufacturing and Material Handling

Deliverable 5.5
Evaluation of the developed toolchain

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Abstract:	This Deliverable is dedicated to 3D **planning, simulation** and **real-time visualization** of Material Handling and Smart Manufacturing systems addressed by the OPTIMUM project. The aim is t**o evaluate the tool chain starting with planning and sales activities and to then simulate and visualize in 3D.** It details the implementation and development of OPTIMUM demonstrators in WP6.

Keywords:	material handling, smart manufacturing, 3D visualization, software development, virtual reality, supervision, real-time visualization, crane

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Executive Summary

This document gives an overview about a potential workflow, enabled by the toolchain of software applications which were developed in the OPTIMUM project.

The usage of tools for various aspects during different stages of the engineering process will be presented in this deliverable.

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1 Introduction

The overall idea in the OPTIMUM project was to apply a 3D-Tool Chain from the beginning for planning and visualization, in a later stage utilization of these results to support implementation and commissioning as well as process optimization comparing the real factory with the virtual factory (as digital twin) and real time visualization for remote monitoring.

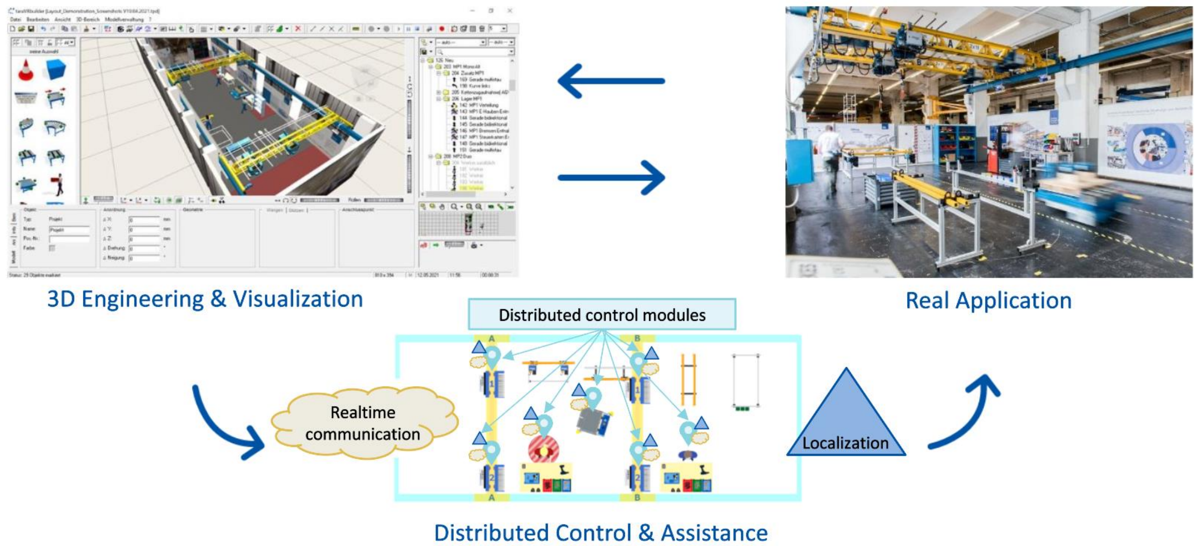

Figure 1 OPTIMUM overall idea

The following workflow works well when setting up a material handling system based on OPTIMUM technologies.
It includes the main steps of the engineering process. Starting point is the customer inquiry, endpoint the digital twin of the implemented material handling system.

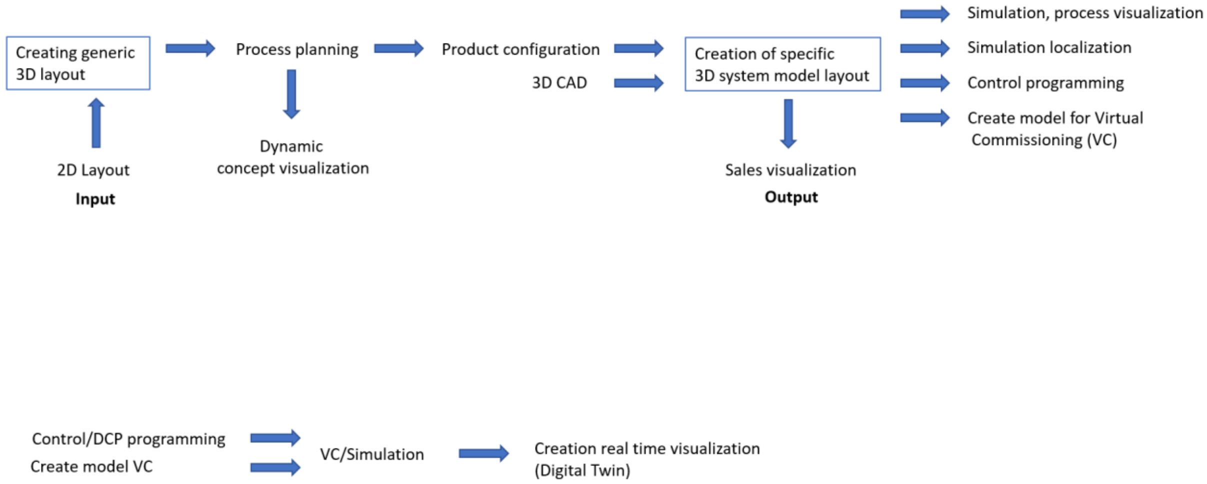

Figure 2 Engineering Workflow supported by OPTIMUM achievements

2 The use of 3D tools in the planning and sales phase

2.1 Layout and process planning

The German demonstrator was described, planned and implemented by the partner Demag Cranes & Components GmbH. During the project, the Demag Research Factory was planned and an assembly process utilizing innovative assistance functions from OPTIMUM was described as a use case. In addition to the operators, the resources required for this assembly are two cranes with 2 trolleys each, a forklift, and an Automated Guided Vehicle (AGV).

The first 2D-drawing for the layout was done by AutoCAD and imported into the planning tool.

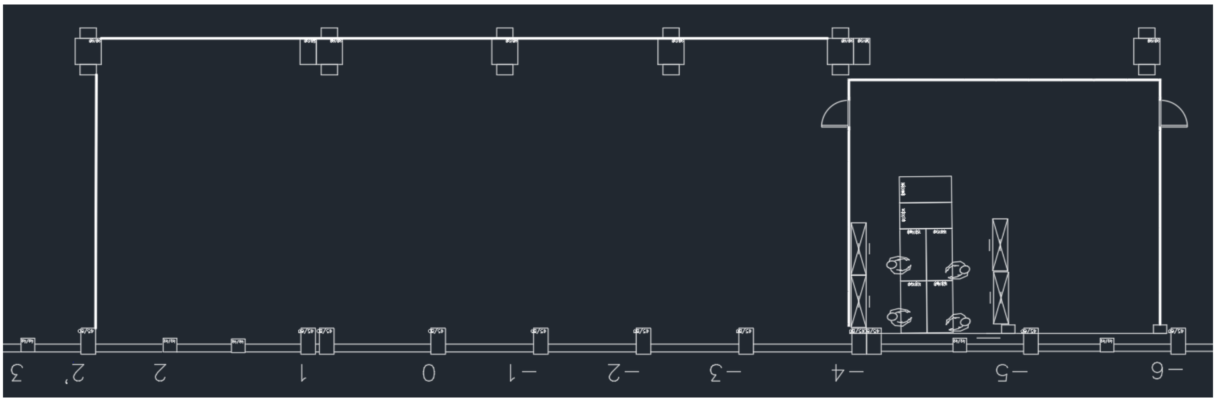

Figure 3 Shopfloor 2D drawing from AutoCAD

3D models of the products and the components needed for the assembly process along with necessary jigs and fixtures, were transferred from the Catia design software.

Figure 4 3D models of fixtures and gigs from CATIA

After arranging all those imported components in the factory layout, the next step is to define processes.

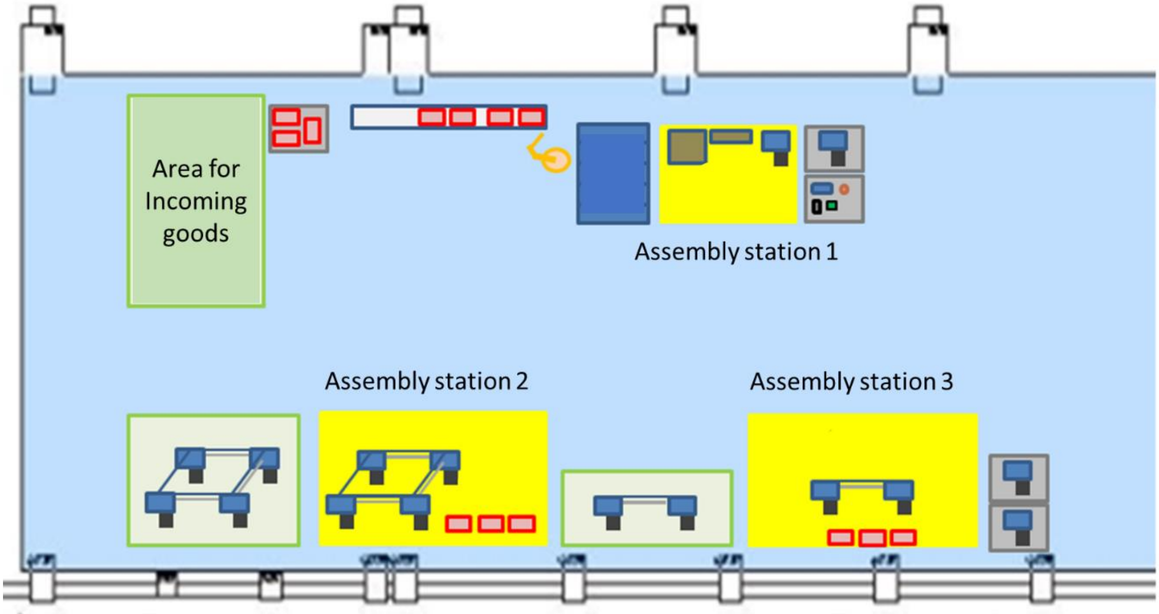

Figure 5 2D concept sketch

Based on a 2D sketch, all transportation rules as well as pick and drop points can be implemented in the 3D planning tool.

After defining all the processes including routes, assembly steps and process times, 3D-models of the material handling machines like cranes and AGVs will be imported to replace the generic 3D objects.

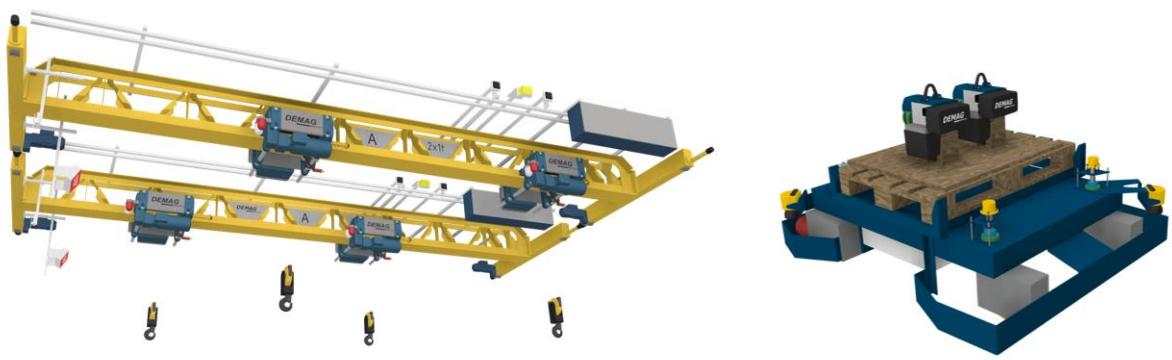

Figure 6 DEMAG products, designed in CATIA

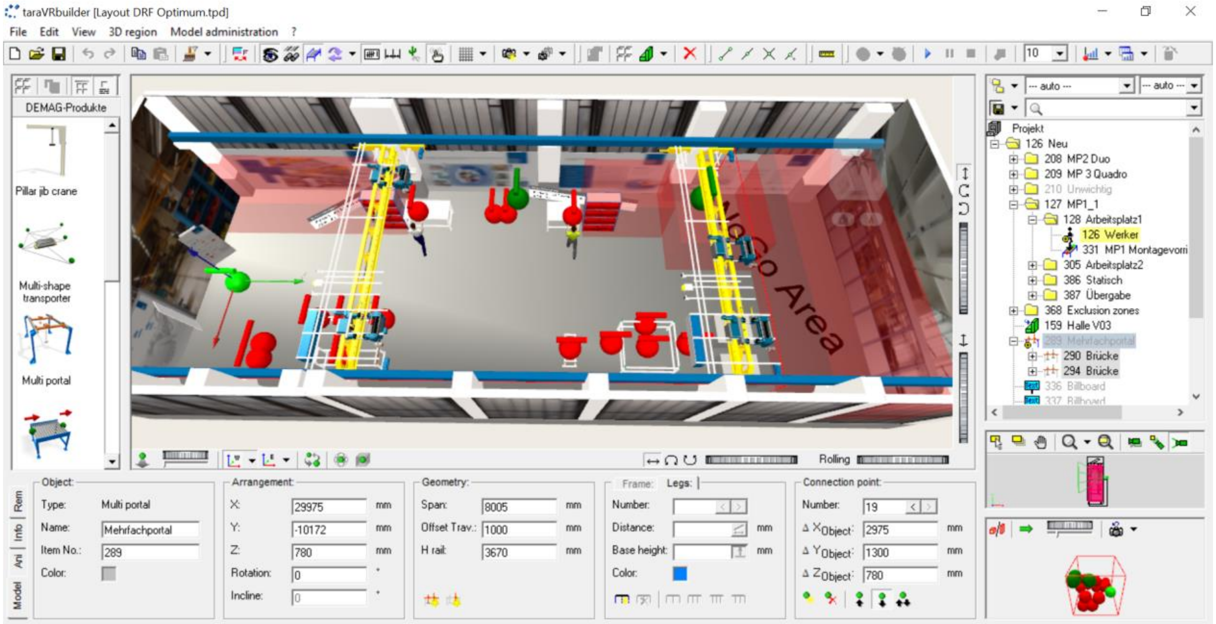

Figure 7 3D factory model including crane pick and drop points

The result is a 3D model of a factory including process data and product information.

2.2 Sales presentation

Currently, sales staff and qualified customers can download drawings and, if available, 3D data of the cranes after using a product configurator.

Depending on the product, the potential customer is provided with data from 2D or 3D drawings in pdf format up to real 3D models in different CAD formats.

The methods developed for sales presentation in OPTIMUM allow to visualize the products in their planned area of use.

The following forms of presentations are supported:

Photorealistic images:

The planning software has been extended with an additional render mode. This allows the 3D model of the plant from the planning process to be used as source data for creating attractive photorealistic images.

Figure 8 Rendered picture for marketing and sales presentation

Videos

In the planning software, the dynamic processes including their key figures such as speeds, accelerations, production, and transport sequences have already been defined and animated.

After adding a round trip, videos can be created, which give the viewer an overall view of the planned factory floor and its processes. The created videos can be used in customer presentations as well as for marketing purposes.

VR presentation - with and without the use of head mounted displays (HMD).

In the most basic case, VR presentations can be made directly on a PC/laptop via a connected large screen. This allows a group of people to follow live navigation through a virtual plant model.

With additional use of VR goggles, e.g., Oculus Rift or HTC-Vive, the viewer can adopt different perspectives in the virtual model of the plant floor and observe the dynamically running transport and manufacturing processes. This provides an excellent spatial impression of the customer´s future material flow and manufacturing plant.

Figure 9 Live-VR-Presentation for the Audience at DEMAG´s Customer Day

Augmented Reality

The Augmented Reality - application enables the product presentation with the help of mobile devices in an already existing application environment.

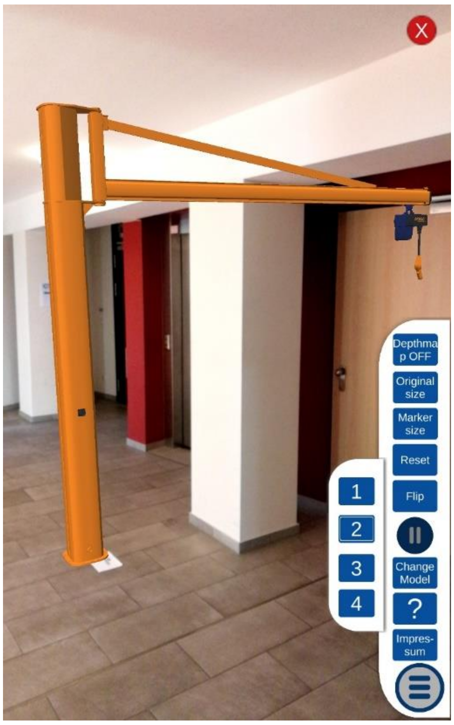

Figure 10 Augmented reality application for product presentation

3 Data provision for further engineering steps

3.1 Data format

During the layout and process planning phases, a lot of data and requirements for the future Material Handling (MH) system are already collected and stored in the planning software.

This information is needed as input data in further steps of the engineering process. In OPTIMUM, concepts have been developed to describe and exchange these data in an open form. The data collected up to this point in the project can thus be made available to all subsequent engineering disciplines.

For this reason, the XML-based format AutomationML is used as the exchange format. Its goal is the holistic description of manufacturing plants and factories. Originally initiated from the automotive industry and universities, it is used to describe resources, processes, and products as well as their relationships to each other. The members of AutomationML e.V. develop so-called role class libraries to describe objects and processes in a standardized way.

In the OPTIMUM project, new role classes were developed, partly based on white papers already published by AutomationML e.V.

The planning software taraVRbuilder has an AutomationML interface. During the project, this was extended in such a way that, for example, the configuration data as well as parameters of indoor cranes, layout information, context awareness, etc. can be made available and applied in the tools used for the engineering process.

During the project AutomationML was used to transfer data

- From tarakos-tools to ifak's Distributed Control Plattform (DCP) application DOME (Distributed Object Model Environment)
- From tarakos-tools to Comnovo's simulation tool for localization systems

The planning tool also provides various options for export of geometry information. Available are VRML, dxf, obj, stl or Collada files.

3.2 DCP configuration in DOME-Studio

DOME Studio is used for developing and configuring the distributed control application. The configuring process of the crane application includes for example:

- Creation of processes corresponding to the number of cranes
- Instantiation of objects corresponding to the number of trolleys on each bridge
- Configuration of properties related to the crane functionality e.g., default speed, max/min speed…
- Configuration of properties related to the shop floor e.g., boundaries, No-go areas…

The configuration of a distributed control application in DOME Studio is shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**. The configuration consists of two processes (each in a grey box) corresponding to the two cranes. Each process contains multiple objects, which can have different properties. These properties allow the application to be adapted to different setups. For example, in **Fehler! Verweisquelle konnte nicht gefunden werden.**, an object for the collision detection function is shown. The object has properties that allow the developer/user to define the boundaries within the crane can travel.

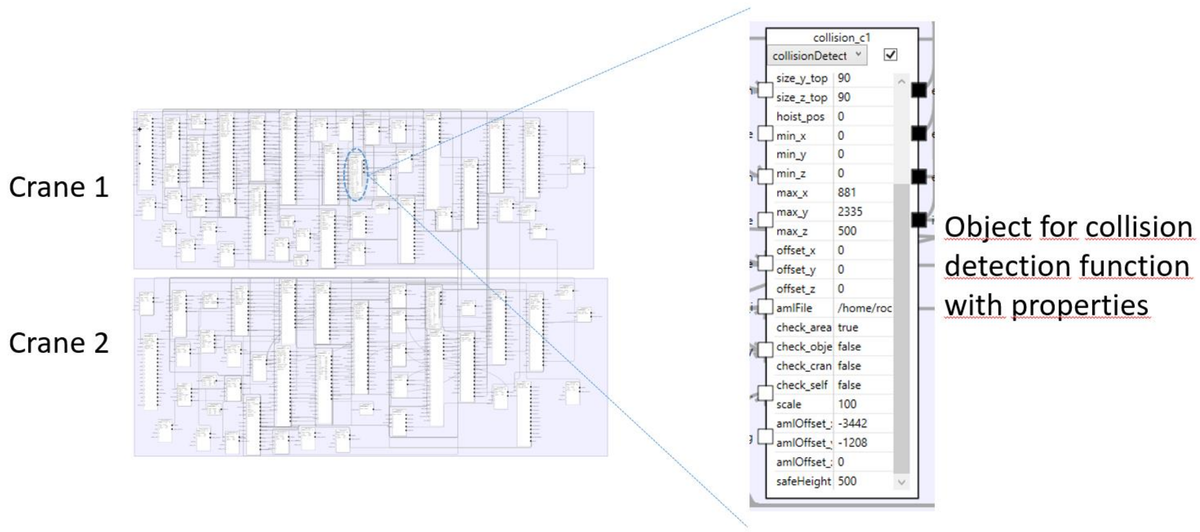

Figure 11 Configuration of the distributed control application in DOME Studio

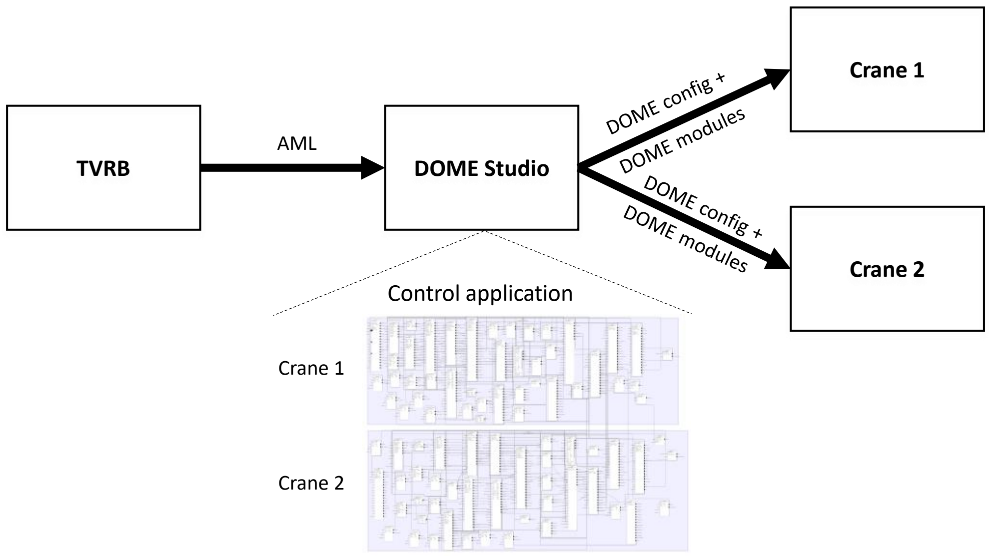

Figure 12 Data provision from taraVRbuilder to DOME Studio

3.3 Virtual commissioning

To enable testing of the control software (DCP) prior to deploying it on the crane in a workshop, a corresponding simulation model must be created first.

For this purpose, geometry models and information about the plant configuration are taken from the planning tool taraVRbuilder (TRVB) and transferred to special behaviour models for virtual commissioning. In addition to the plant information, structure and product parameters of the cranes, AGVs (e.g., max. speeds, accelerations, etc.) and information on context-awareness are used in the simulation model. One example is the definition of no-go areas, which the crane may not approach.

To enable high-performance communication between the control system and the simulation model during virtual commissioning, an interface between these two tools was developed and optimized.

With the help of virtual commissioning, many functions, including the newly developed innovative assistance functions, like for example “go-to”, “come-to-me”, “follow-machine”, can be tested prior to an installation in the hall.

The operator’s interactions with the crane can be tested, i.e., first all conventional signals and commands for each crane component moving forward/backward or lifting and lowering.

The next step is to check the correctness of the inputs via a smart device, i.e., the data stream from the smart device to the controller as well as the execution of the new assistance functions.

After the basic functions have been tested, the productivity and efficiency of the distributed control system can be verified.

Users can run through the same operator scenarios on the virtual commissioning model and compare the time required for cycle time with and without innovative assistance functions.

Furthermore, the simulation models can be used to optimize processes. For example, different arrangements of stations, warehouses and assembly stations can be tested, and the resulting cycle times can be determined. The effects of relocating No Go Areas and Restricted Areas on cycle times can also be determined.

With the help of VC, errors in the control system can be detected quickly. When checking the assistance functions (e.g., come-to-me, go-to, follow-machine), the following errors can be detected, for example:

- Crane is too slow or to fast compared to the "follow object", i.e., the worker or the AGV
- too slow, distance between cranes too large
- second crane does not start
- Crane moves too far, does not stop
- Target is not reached
- Violation of No-Go Area
- Emergency stop does not work

In addition, checking the communication between the IIOT component and the distributed controller can also be a goal of the VC.

3.4 Realtime visualization

The data interface for creating the 3D real-time visualization is largely based on the technology used to create the Virtual Commissioning model. The same initial data, e.g., the 3D models, are utilized, but the data mappings differ.

They do not reference special behaviour models, but the transfer and assignment of position and status data of cranes, vehicles and operators.

The exchange between planning tool and real-time visualization is based on 3D and AutomationML data.

3.5 Localization-system simulation

Simple models were developed for the planning software taraVRbuilder to place so-called localization anchors in the 3D model of the factory hall and to visualize their theoretical range in a roughly simplified form. This represents an initial tool for the planner, but for detailed planning and simulation, software specifically designed for this purpose, such as the one developed by Comnovo, is required.

Concepts were developed for the transfer of information about positions and parameters of the localization components as well as highly simplified obstacles for the transmission of the radio waves.

Comnovo has prototypically developed a way to support the installation of radio-based localization systems. The developed tool graphically displays the structure of anchor positions and the resulting geometrically determined position accuracy. This makes it possible to evaluate the placement of the anchor nodes and to adjust them if necessary. Furthermore, a JSON-based interface was defined with Tarakos to ensure interoperability between these tools.

Figure 133 shows the implementation of the tool in a Graphical User Interface (GUI) realized with QT. Besides the placement of anchors via Drag&Drop one can place obstacles on a map of the environment. It is furthermore possible to directly transmit this information to anchor nodes via air interface, to enable a scalable construction of an Ultra Wideband (UWB) localization system.

The construction of a radio-based localization system is associated with some hurdles that can lead to dysfunctionality of the system. On the one hand there must be a direct and stable connection between anchors and tags, and on the other hand, the geometry with which the anchors are placed in the environment must be taken into account. For example, a tag must "see" three anchor nodes (Triangulation) to calculate a position in a plane, but in addition, these anchors must not lie on a line. The heatmap on Figure 133 shows the planning of anchor positions in the Demag Research Factory. A high value (green) indicates a good anchor constellation while red areas indicate an insufficient constellation. For demonstration purposes, an obstacle was inserted to show the effect of careless planning.

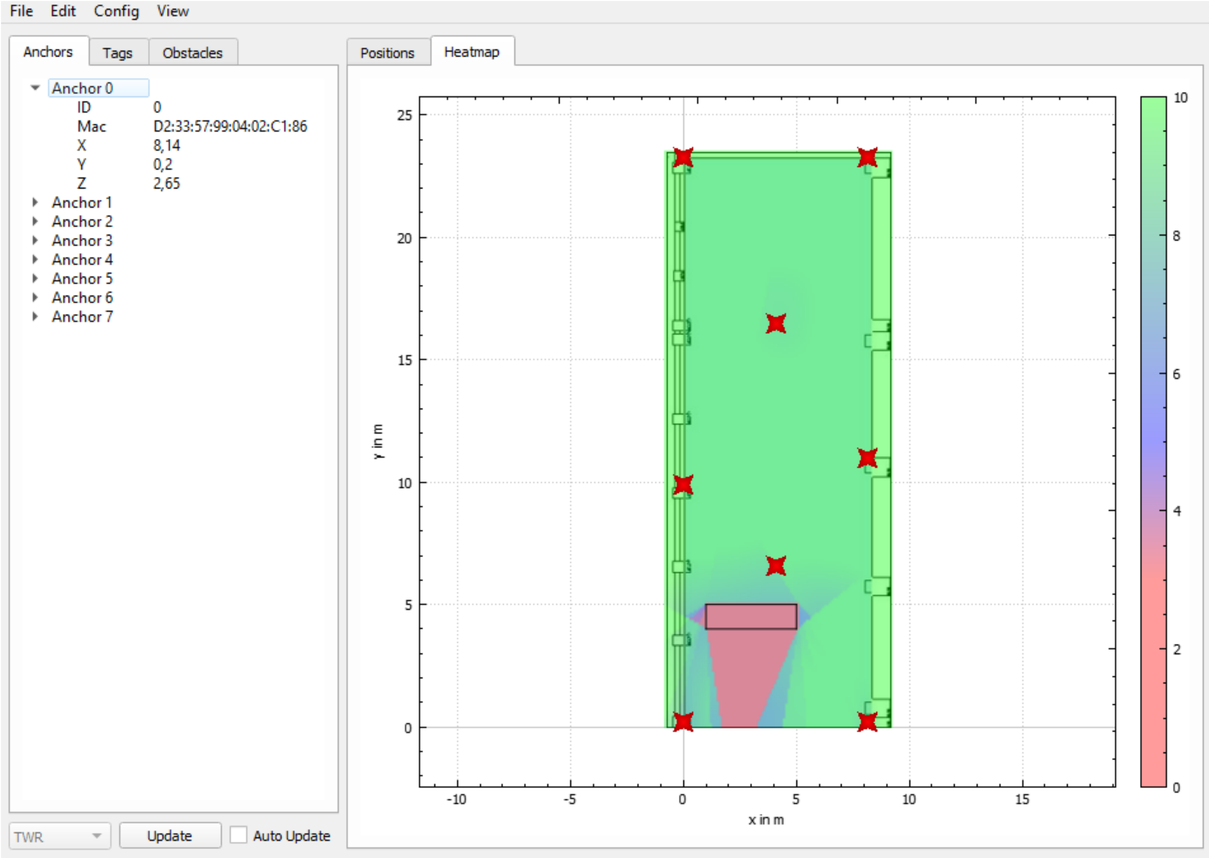

Figure 13 Planning view of the Demag Research Factory

3.6 Export background picture to mobile-App

The project partner ERSTE developed an application for mobile devices, which can control the hall crane via an IIOT platform using the innovative assistance functions developed in OPTIMUM and to visualize positions and operating status of the cranes.
A 2D image of the workshop is required as a background for this application. This is provided by a true-to-scale image export from the planning tool.

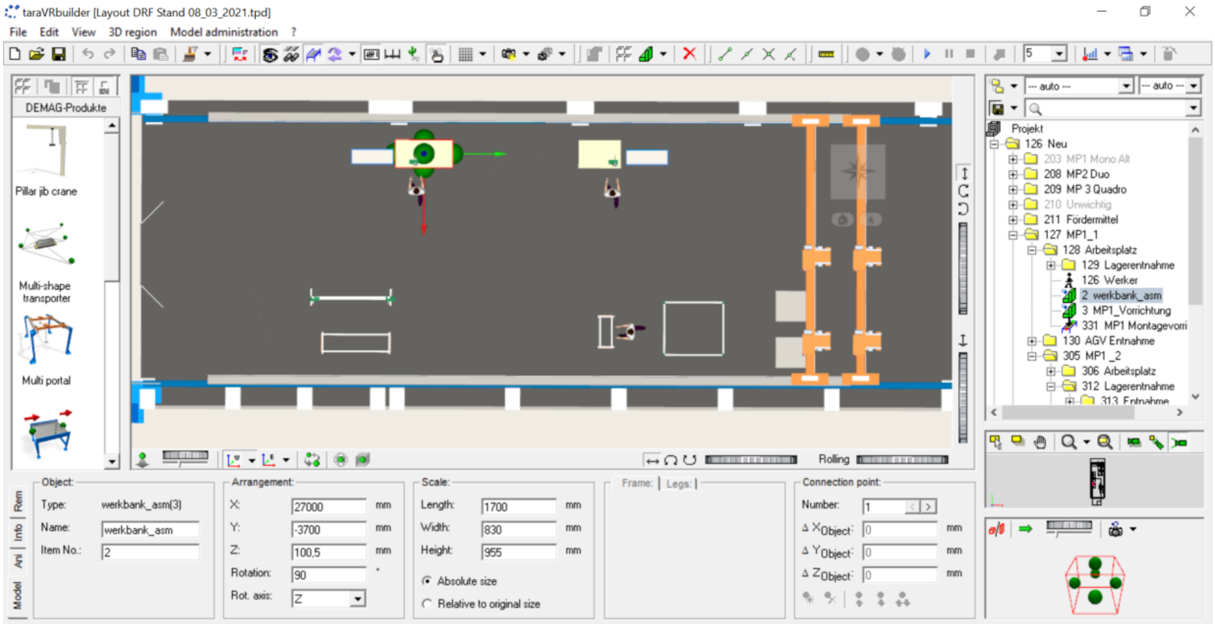

Figure 14 Orthographic view for real-scaled-picture export

4 Toolchain overview

Users can start the design of a 3D factory layout from scratch by using the software tool taraVRbuilder.

But generally, the workflow starts with an existing building-layout, mostly created in AutoCAD 2D. Often also machines, conveyors, stores and warehouses are included.

Depending on the internal structure of layout files, users can import dxf-files and place 3D objects manually or define mapping rules for an automated setup of the 3D factory layout.

Generic 3D-objects from taraVRbuilder libraries are used to design the 3D factory layout in both cases.

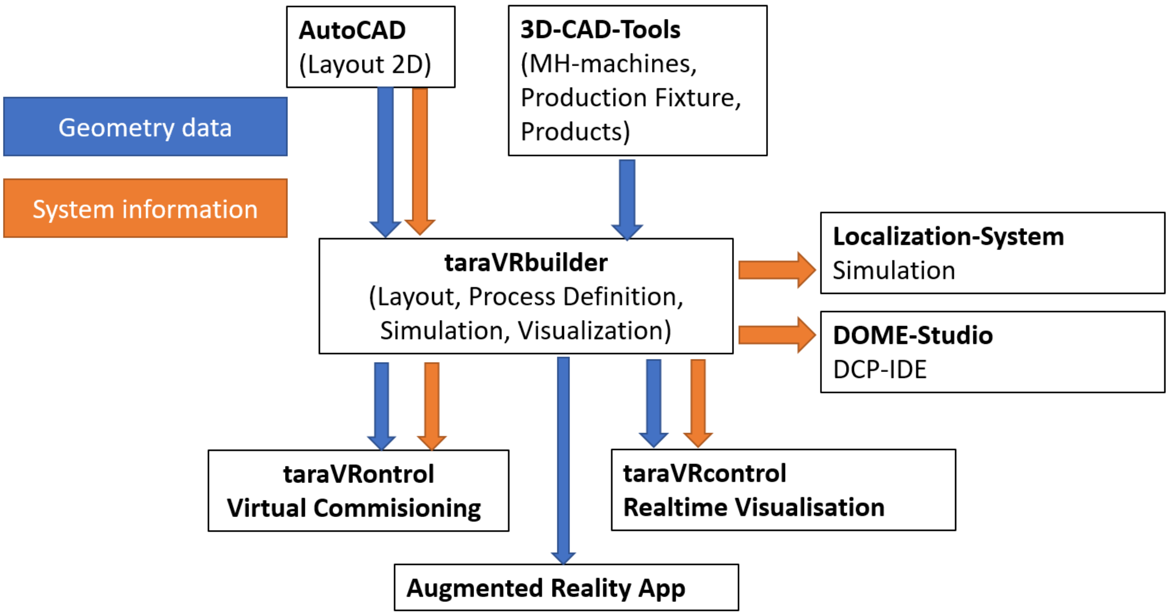

Figure 15 Data exchange for geometry and process/system information

The planning tool taraVRbuilder is used to create 3D visualizations, but also provides system information on topology, process data, material flow descriptions, machine parameters and 3D data.

5 Abbreviations

2D	Two-dimensional
3D	Three-dimensional
AGV	Automated Guided Vehicle
AutomationML	Automation Markup Language
CAD	Computer Aided Design
DCP	Distributed Control System
DOME	Distributed Object Model Environment
DXF	Drawing Exchange Format
GUI	Graphical User Interface
HMD	Head mounted displays
IDE	Integrated Development Environment
IIoT	Industrial Internet of Things
JSON	JavaScript Object Notation
MH	Material Handling
STL	Standard Triangle Language
TVRB	taraVRbuilder
UWB	Ultra-Wideband
VC	Virtual Commissioning
VR	Virtual Reality
VRML	Virtual Reality Modeling Language
WP	Workpackage
XML	Extensible Markup Language