RE4DY

MANUFACTURING DATA NETWORKS

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2	CHALMERS TEKNISKA HOGSKOLA AB	Chalmers
3	INTERNATIONAL DATA SPACES EV	IDSA
4	VOLKSWAGEN AUTOEUROPA, LDA	VWAE
5	ASSECO CEIT AS	CEIT
6	UNINOVA-INSTITUTO DE DESENVOLVIMENTO DE NOVAS TECNOLOGIAS-ASSOSIACAO	UNI
7	FILL GESELLSCHAFT MBH	FILL
8	AVL LIST GMBH	AVL
9	VISUAL COMPONENTS OY	VIS
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11	ATLANTIS ENGINEERING AE	ATLANTIS
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14	UNIVERSITETE I OSLO	UiO
15	GE AVIO	AVIO
16	ENGINEERING-INGENIERIA INFORMATICA SPA	ENG
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18	ATOS IT SOLUTIONS AND SERVICES IBERIA SL	ATOS IT
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19	KATHOLIEKE UNIVERSITEIT LEUVEN	KU
20	NETCOMPANY-INTRASOFT SA	INTRA
21	NOVA ID FCT - ASSOCIACAO PARA A INOVACAO E DESENVOLVIMENTO DA FCT	NOVA
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23	ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS	CERTH
24	GRUPO S 21SEC GESTION SA	S21SEC
25	UNIVERSITAT POLITECNICA DE VALENCIA	UPV
26	CONSIGLIO NAZIONALE DELLE RICERCHE	CNR
27	SOCIEDAD ANDALUZA PARA EL DESARROLLO DE LAS TELECOMUNICACIONES SA	SANDETEL
28	SWITZERLAND INNOVATION PARK BIEL/BIENNE AG	SSF
29	GF MACHINING SOLUTIONS AG	GFMS ADVMAN
30	FRAISA SA	Fraisa SA
31	SIEMENS SCHWEIZ AG	SIE

List of Acronyms/Abbreviations

Acronym / Abbreviation	Description
DoA	Description of Action
PoC	Proof of Concept
TEF	Testing and Experimentation Facility
WP	Work Package

Executive Summary

RE4DY has carefully selected a set of pilots to establish high economic value ecosystems building on previous successful digital manufacturing demonstrations and lighthouse projects setting the foundations for the embryonic European Industrial Data Spaces (EIDS); e.g., Boost4.0, DIMOFAC, QU4LITY. RE4DY will establish manufacturing & supply value network ecosystems in automotive (VWAE-CEIT extending current Catena-X automotive data space initiative), eBattery (AVL-FILL extending current AT IPCEI battery project).

RE4DY pilots address both machine tool builder and product manufacturing resiliency perspectives; as well as joint optimisation of smart product and production at both engineering & operational phases. The use cases address also the ones with highest EU priority for development of common manufacturing data space, i.e., Logistics of the Future, Megafactory & E-battery design, Circular Machining and Distributed Green Zero-X Manufacturing. These processes will be applicable to many sectors; so, with high growth and replication potential.

The objective of D4.1 is to provide a detailed overview on the two pilots which constitute the "Large-Scale Trials of Resilient Smart Connected Factory 4.0 Process Engineering". D4.1 will present the different business cases and related requirements (business and technical). A first iteration on the main KPIs to be evaluated will also provided and a detailed description of the data sources to be used in each pilot.

The "Logistics of the Future" pilot lead by VWAE, will focus on the assistance in the decision-making to the logistics specialist about the best course of action depending on the production planned and depending of the inventory available for vehicle manufacturing. VWAE is committed to fully address a resilient logistic generative design & planning approach. This approach will address a more automated yet supervised generation of logistic processes scenarios driven by AI and digital-twins for simulation, enabling the possibility to analyse different concepts of warehousing, picking and line feeding, creating an autonomous internal supply chain, enabling human workers to fine tune, select and refine the scenarios proposed by RE4DY generative models. The ultimate goal is to validate the human-centric generative design and planning of the intra-logistic process and cognitive product development framework.

The "Megafactory & E-battery design" pilot lead by AVL-FILL, will be mainly addressing the following objectives: (i) Model-based and big data-driven engineering process, cognitive twin realistic process simulation on battery engineering and manufacturing process.(2) AI-powered Process Models Optimisation Engine to calibrate modal analyses out of sensor data real-time information in the battery innovation center (BIC) and production line. (3) Flexible center for production-oriented manufacturing of proto battery modules and packs (4) Close-loop feedback to product development (DfM - Design for manufacturing) and provide industrialized designs and processes "ready for ramp-up" (5) Leveraging of engineering business for battery development (6) Verify Eco-Design products in respect to recycling and cost.

1 Introduction

1.1 Context and scope of this document

The scope of this deliverable is to describe the work that has been done and the research has been conducted in Task 4.1 "Pilot set-up, resilient factories & supply chain design and value network data preparation".

T4.1 is focused mainly on the pilot set-up, value network service design and data preparation (consume, publish, update) via marketplace and integrated via sovereign data fabric, using the core common concepts, strategies and continuum frameworks provided by WP2 and qualified WP3 toolkit to ensure autonomous data engineering and semantic interoperability in value networks lifecycle digital thread data fabrics. Capitalizing on RE4DY active resiliency strategies (T2.2), within this task UNINOVA was in charge of the design of a pilot set-up, value network service design and value network data preparation and compliance for the necessary "Data as a Product" to be applied to the connected logistics for automotive (VWAE, CEIT) and the collaborative ecosystem smart product for smart production design (SP2) information for electric battery pilots (AVL, FILL, VIS).

The report is focused on providing a detailed description on each of the two pilots. The description focus on: (i) Description of each business scenario within each trial explaining in detail; (ii) Explanation of the current situation/scenario in the company; (iii) Directives and regulations; (iv) Description of the future scenario; (v) Business objectives; (vi) Expected benefits, and; (vii) Business indicators.

The chapter on "Data Sources and Data Characterization", is intended to provide a means to collect information on RE4DY pilots relating to their plans for use of standards, data management and data governance, as well as security, safety, privacy, trust and resilience.

1.2 Relationships among other deliverables

WP4 is tightly aligned with WP2 and WP3. Within this respect, D4.1 will take as input, the main outcomes from deliverables:

- "D2.1 - Manufacturing & supply chain active resiliency model", which present the first release of the Digital 4.0 Continuum Reference Architecture for Active Resiliency and provide elicitation to pilot requirements.
- "D2.2 - Digital 4.0 continuum reference framework_First Version" RE4DY Reference Architecture (RA) aiming to facilitate the implementation of digital continuity across Digital Threads, Data Spaces, Digital Twin workflows and AI/ML/Data pipelines.
- "D3.1 - Resilient and sustainable Data as a Product computing and data space", where the objective is to establish a network of Testing and Experimentation Facilities (TEFs) and European Data Spaces for qualifying digital 4.0 continuum open systems & OSS tools.

This deliverable will provide output to "D4.2 - Scale up & on-site validation & revised KPI assessment_Process Engineering", which will report on the development of appropriate APIs for connecting to the different data sources to RE4DY virtual data ecosystem platform.

2 VWAE Pilot

2.1 Use-case sequence

The Volkswagen Autoeuropa trial for RE4DY will focus on an internal logistics process called GT Process however, in order to understand properly how this process works there are a few concepts to grasp.

First thing to consider is that within the Volkswagen Group there are two main types of containers used for logistics processes. There are GLT (Großladungsträger) and KLT (Kleinladungsträge).

GLT's are larger containers used for larger parts. These type of containers usually hold smaller amounts of parts depending on their size and form.

Figure 1 - GLT Container type 114888.

KLT's are small size containers that usually carry smaller parts in a bulk format, once more; this also depends on the size and form of the parts loaded into them. The use case will focus on this container type.

Figure 2 - Several KLT laid out in the GT Process at Volkswagen Autoeuropa.

Smaller containers, like KLT, come from the supplier in bundles neatly stack together, the current designation for this configuration is GT: KLT Gebinde.

From a conceptual perspective, storing parts in GT bundles, it is not much different from GLT. However, for the GT bundles, the picking method dictates the storage location within the warehouse. These GT bundles hold considerable amount of parts and so, around the assembly area, the logistics peripherals/containers found on the several points of fit are GLT's, sequencing racks (made on the logistics supermarkets) and individual KLT's. There is no delivery of GT bundles as a whole into the point of fit. It goes back to the fact that high amount of parts characteristically found on these type of containers, are not desirable to go into the assembly line thus, delivery of the individual KLT is done instead. For this reason, the storage of GT bundles at the warehouse goes into two separate locations/processes:

1. Low runners parts go into shelve storage concept. The picking of the individual KLT's is done by a specific equipment to reach the different shelves: order pickers;

Figure 3 - Order Picker at a KLT Shelve Storage.

2. High runners parts go into areas called Bahnhof. GT bundles with higher demand are located in this specific area because they need to be easily accessible by the operators in the tugger trains delivering parts from the warehouse to the assembly line.

Figure 4 - GT Process at the bahnhof area.

GT Process is the designation given to the process of picking high runners parts in the Bahnhof area.

The key factor about this process is adaptability to marketing demands through monthly adjustments of the parts considered high runners. In other words, although the targeted production number is constant on a daily basis, the volume between the different model specs usually vary a lot due to external influences. These external influences most often relate to fluctuations of preferences in the market or to entropies on the supply chain of the suppliers of a plant.

Dealing effectively with situations like these, boils down to high levels of process flexibility without significant financial losses: high resilience.

Currently at Volkswagen Autoeuropa, monthly updates of this process are still challenging to accomplish because, the insights, which, generate an optimum scenario, are not easy to deploy. This affects the parts designated to the GT Process and the efficiency and occupancy of line feeding equipment, which are required to deliver these parts into the assembly line.

Recent developments in digitalization enabled the establishment of the bedrock of an autonomous internal supply chain concept. Implementing and harvesting the full potential of an autonomous internal supply chain might be too ambitious on a medium term therefore, with the current resources available the wisest strategy is to start with a process that:

1. would be possible to extract financial benefits on a monthly basis;
2. has high flow of data already available;
3. has the potential to extract analysis or insights of different steps of the process, such as: line feeding asset analysis, parts demand analysis and shopfloor operation for deployment of new system configurations.

The first cluster to work on is, the enhancement of the digital capabilities of the planning specialist, meaning that he or she must be able to perform analysis of the process, reconfigure the system configuration to fit the current production scenario and then, deploy this optimal scenario by informing the stakeholders involved in the process. This flow of information must be seamless and the stakeholders must have all the digital support required to make it so.

The second and last cluster to work on is, the simulation of the different scenarios within the chosen internal supply chain process in order to take full advantage of the assets deployed on the shop floor. This step, is particularly interesting because, it must allow the logistics planning specialist to assess the efficiency of each asset and extract possible solutions of optimization which, will reduce even further the logistics costs of the internal supply chain process at Volkswagen Autoeuropa.

The steps and activities identified for implementation are:

1. Select a process within the internal supply chain at Volkswagen Autoeuropa: identify a simple process which can bring substantial financial benefits if digitalization/automation is enhanced.
2. Study its bottlenecks, find tasks which can benefit from digitalization/automation and make them resilient, flexible and adaptable: identify what are the activities within the process which consume too many

resources or require too much effort to deploy. Then, pick which are transformable to a digital environment in order to decrease their effort.

3. Create the process scenario on a digital environment and investigate the optimal asset configuration: simulate on a digital environment the process and find the optimal usage of the line feeding assets linked to the use case.
4. Extract the most of the digital environment by exploring different solutions optimizing as much as possible the entire operational shop floor area: study different locations for the use case, extract insights and investigate financial attractive scenarios by reallocating the whole process to other areas of the plant.
5. Outcome analysis, aim for the optimal process and prepare the system to adapt to any entropy caused by internal or external factors: study, iterate, and reinforce the know-how of the organization to enhance adaptability and flexibility of the use case. Study machine learning algorithms and further explore options of autonomous/automatic planning in the logistics use case.

2.1.1 PoC definition

Autonomous / Automatic Planning

Monthly routine to extract and publish directly the optimum scenario to key stakeholders of the internal supply chain at Volkswagen Autoeuropa. Logistics planners are able to perform adjustments/study different scenarios and as soon as they validate the optimum scenario, the information flows digitally throughout the organization.

Information about the optimum scenario is clear to everyone and thus, each stakeholder knows which changes are required to achieve it.

These scenarios must be deployed effectively on a monthly basis for the best possible financial gains in the GT Process.

Shop floor Implementation

Efficient communication to the stakeholders on shop floor level with digitalization to enable direct remote updates through e-papers. This is to smooth the operation by displaying clear information to all members of the operational team: from the ones responsible to coordinate and physically implement changes and to the ones responsible to move and deliver the parts from the warehouse to the point of fit.

Considerable reduction on the planning process since it is no longer required from the logistics planners to update the process physically on the shop floor. With the deployment of e-papers, updates to the process are achievable remotely.

Resource Optimization

After the definition of the optimal scenario of parts in the GT Process then it is time to optimize the resources required to deliver those parts.

Upload new scenario of GT Process into the simulation tool and analyse the time required for each route and overall equipment efficiency. Test different scenarios, aim for the best financial solution. Introduce ML based on historical data, to explore these scenarios as accurately as possible.

Item 1: manual, mundane and laborious planning/communication, which greatly increases the time required to update the system.

EXPECTED RESULTS:

The expected results from item 1 is to relief planners of mundane tasks required in the planning and communication stage when updating the GT Process. The logistics system updates for the current ERP scenario and then, the planner validates and deploys the optimum part selection for the GT Process, followed by an automatic communication mechanism to inform all key stakeholders of the update process and on how to proceed for the deployment of the optimum GT Process. The communication routine after each update must be easy to follow and deployed with significant automatic triggers to ease the process information flow, all the way from the planner until it reaches the shop floor.

From the deployment of this process planning, one can expect significant gains in time throughout each stakeholder involved in the process. This is possible thanks to an increase in digitalization and communication actions automatically triggered to the key stakeholders.

Additionally, operational reaction times decrease and systems adaptability to unstable logistics environments increases.

Item 2: inefficient deployment of updated logistics processes

EXPECTED RESULTS:

Speedy updates are useless without a strong support on digitalization and communication to the shop floor. Thanks to the use of E-Papers there is a significant increase in digitalization in the procedure of updating the GT Process. With these devices, upon the moment the system updates, the stakeholders from planning to shoo floor are immediately aware of the new optimum scenario. Additionally, during a transitional stage, it displays the current and new part number allocated to a given location on the bahnhof, thus training and informing the operation of these changes with significant preparation time.

The benefits for this use case come from the preemptive update and communication to the operational team on the shop floor through a sophisticated communication methodology thus, shortening reaction times by informing and training the operational team, as soon as the decision is known within the higher hierarchy of the organization.

Item 3: resource optimization

Resource optimization on the Logistics system at Volkswagen Autoeuropa is complex. With the aid of a simulation tool one can expect quick studies of multiple scenarios with high degree of confidence. Therefore, the GT Process is an excellent stepping-stone to start with this initiative.

The expected result is to enable quick process/resource optimization starting with a simpler process (GT Process) and then move on to the entire Logistics system.

In a near future, where all logistics processes are within a digital twin/simulation tool, it would be possible to test multiple scenarios to accommodate the demand fluctuations and disruptions affecting the Logistics system. This would be that the optimal scenario is constantly being pursued resulting in significant financial gains within the logistics ecosystem as well as increasing the robustness of the entire chain by shortening planning time, making the whole process much more agile and adaptable to internal/external factors.

2.1.2 First experimentation results

The first exploratory results to report are about the development of a script to autonomously configure the ideal part numbers for the GT Process. The example below shows the financial savings of the optimal GT Process calculated by an early version of the script applied to the logistics master data file from November 2022.

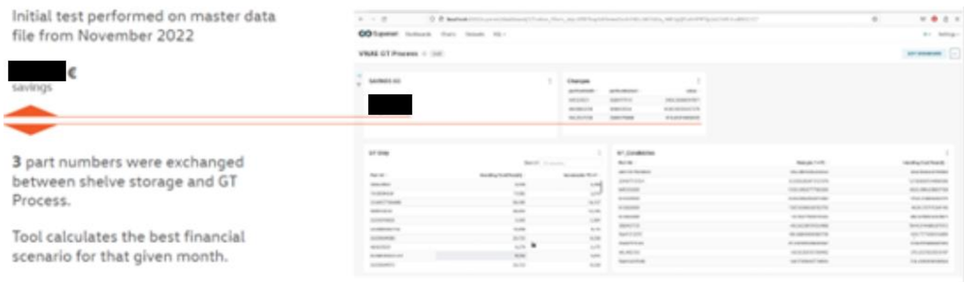


Figure 5 - First try out of script to configure optimal part number configuration on GT Process.

The second early exploratory results to talk about is related to the study of asset optimization.

Thanks to a track and trace technology we can see the operation of line feeding assets in unexpected areas. The detection and correction of these events will obviously, translates into inefficiencies and opportunities of improvement.

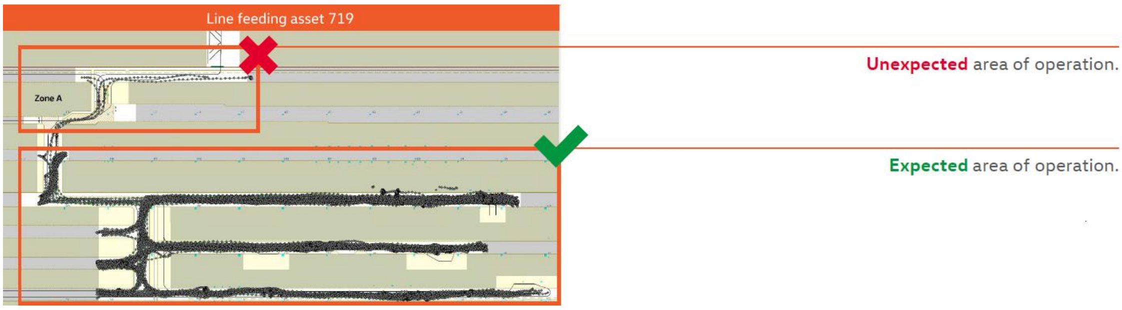


Figure 6 - Operation analysis of line feeding asset number 719.

This initial study/result will set the bedrock for further analysis of asset performance, which, ultimately will result in fleet optimizations in the internal logistics supply chain.

The last early exploratory result is about the validation of the actual asset occupation in the GT Process. This study was done through a simulation tool where the entire GT Process was configured to assess the time and routes taken by each line feeding asset and thus asses the actual equipment efficiency against the theoretical one from the simulation tool.

Figure 7 - Asset occupation of the actual GT Process through simulation.

This early step will enable additional simulations of different scenarios for the GT Process with the added value of obtaining quick assessments of asset occupation in those different scenarios.

2.2 BP1 – Autonomous / Automatic Planning

2.2.1 Business process in detail

Monthly routine to ingest data, extract and publish insights directly the optimum scenario to key stakeholders of the internal supply chain at Volkswagen Autoeuropa (specific process is GT Process). Logistics planners are able to perform adjustments/study different scenarios and as soon as they validate the optimum scenario, the information flows digitally throughout the organization.

Information about the optimum scenario is clear to everyone and thus, each stakeholder knows which changes are required to achieve it.

For the GT Process, in order to extract the best possible financial gains, the optimal scenario must roll out effectively on a monthly basis following customer and marketing tendencies, which result in different consumption trends of part numbers per week.

Currently, these updates are possible although, they are not automatic nor streamlined. There is a considerable effort to account for when communicating changes to the logistics service provider.

In the future the process must have an automatic / autonomous update with overarching communication to the logistics service provider thus, releasing logistics planners time for other tasks.

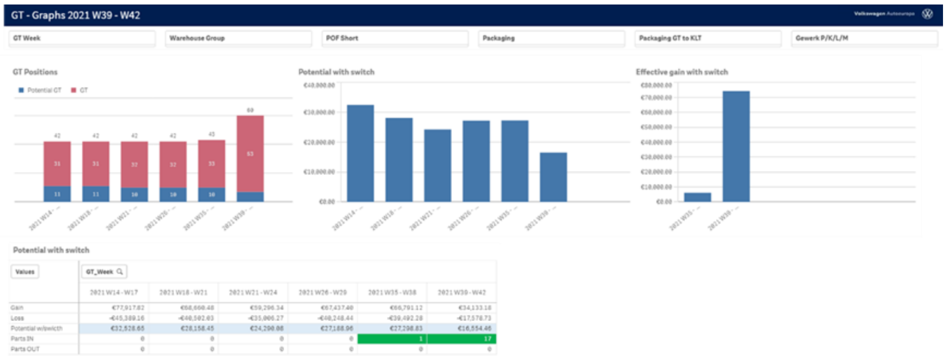


Figure 8 - Current dashboard of the GT Process.

2.3 BP2 – Shop Floor Implementation

2.3.1 Business process in detail

The pilot aims to set efficient communication to the stakeholders on shop floor level with digitalization which, enables direct remote updates through e-papers. This is to smooth the operation by displaying clear information to all members of the operational team: from the ones responsible to coordinate and physically implement changes and to the ones responsible to move and deliver the parts from the warehouse to the point of fit.

Additionally, the pilot sets targets on a considerable reduction on the planning process since it is no longer required from the logistics planners to update the process physically on the shop floor. With the deployment of e-papers, updates to the process are achievable remotely.

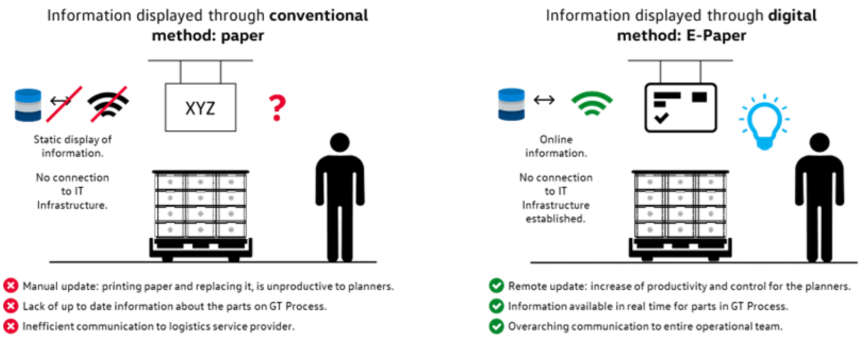


Figure 9 - Current and future scenario with the introduction of E-Paper on the GT Process

2.4 BP3 – Resource Optimization

2.4.1 Business process in detail

After the definition of the optimal scenario of parts in the GT Process then it is time to optimize the resources required to deliver those parts.

The logistics planners, upload new scenario of GT Process into the simulation tool and analyse the time required for each route and overall equipment efficiency. They test different scenarios setting their target for the best financial solution. At this phase, the introduction of Machine Learning based on historical data, is key to expose these optimal scenarios as accurate as possible.

Currently the assembly area is divided into 3 main zones and the planning of routes do not account for sophisticated optimization or integration of routes. Calculation / analysis is done manually by the logistics service provider.

In the future, planning of routes is done through sophisticated process simulation using machine learning, this leads to optimization of line-feeding assets and thus financial savings on the whole internal logistics supply chain at Volkswagen Autoeuropa.

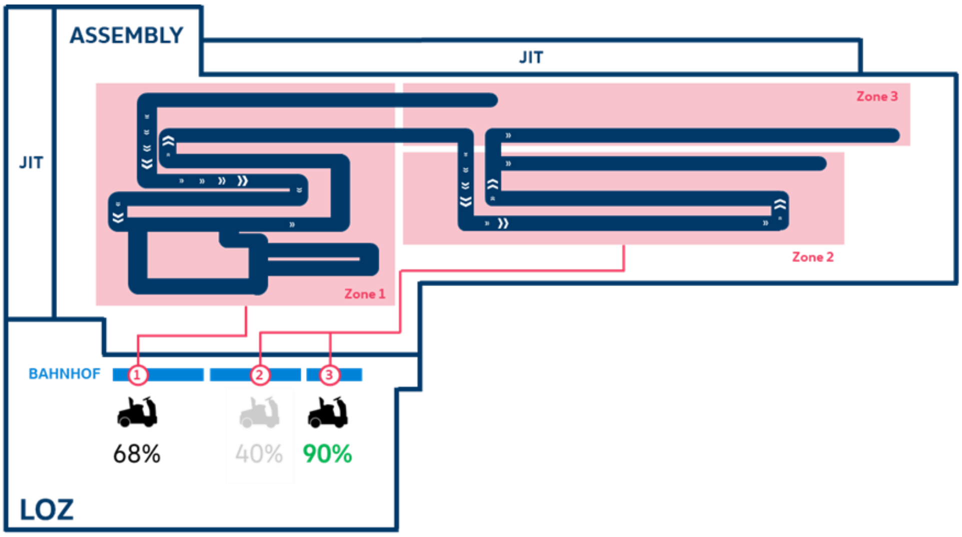


Figure 10 - *Planning of asset optimization operating in the assembly area for the GT Process.*

2.5 Business indicators

ID	BUSINESS Indicators *List the Business objectives expected for the Business Scenario/Use Case*	DESCRIPTION *Give a detailed description of the indicators*	Unit*	Current value	Future expected value	Expected date of achievement**
1	Operating cost reduction: logistics cost for the GT Process	Automated monthly analysis anticipates opportunity for cost reduction of logistics service versus semesterly or quarterly manual analysis. Optimum processes means less effort/costs with logistics service provider on the shopfloor. The dissemination of optimum processes in the internal logistics chain will decrease the product's overall cost	Cost reduction (€)	Confidential	5% increase in savings with GT Process	before 6 months after implementation
2	Changeover planning time shortening	Increase in process flexibility with the reduction of the average time spent conceiving the optimal scenario configuration for the GT Process. All around quicker scenario updates on a routinely basis renders the logistics system flexible and adaptable. Simulation of different GT Process configurations increases system flexibility.	Average time spent in planning phase	No less than 5 workings days with some effort from logistics service provider.	-10%	before 6 months after implementation
3	Decrease of iteration and implementation time	Less time designing optimal solutions/configurations for the GT Process. Quick and autonomous upload to digest GT Process master data decreases implementation times, especially on laborious tasks carried out by logistics planners. Remote updates of E-Papers enable quick deployment of new GT Process configurations. Asset occupation for routes GTA / GTG and GTF are done via digital twin at a much faster pace.	Average time spent on implementation	No less than 8 workings days with substantial effort from logistics service provider.	-10%	before 6 months after implementation
4	Digitalization: improved knowledge on the process performance	Digital workplace with insights to assess and execute optimization with shortened lead times. Key strategic information is displayed through e-paper. Paperless process.	Digitalization capabilities	No control of start/finish GT Process. No E-Papers.	Dashboard to control start/finish GT Process. E-Papers on GT Process.	before 6 months after implementation

Relationship between the different Business Processes:

ID	Indicator	Description	Current Value	Future Value	BP1	BP2	BP3
1.	Operating **cost reduction**: logistics cost for the GT Process	Automated monthly analysis anticipates opportunity for cost reduction of logistics service versus semesterly or quarterly manual analysis.	Confidential.	**5%** reduction	✔		
2.	Changeover **planning time** shortening	Increase in process flexibility with the reduction of the average time spent conceiving the optimal scenario configuration for the GT Process.	> 5 Working Days with some effort from service provider.	**10%** reduction	✔	✔	✔
3.	Decrease of **iteration** and **implementation time**.	Quick and autonomous upload to digest GT Process master data decreases implementation times, especially on laborious tasks carried out by logistics planners.	> 8 Working Days with significant effort from service provider.	**10%** reduction	✔	✔	✔
4.	**Digitalization**: improved knowledge on the process performance.	Digital workplace with insights to assess and execute optimization with shortened lead times. Paperless process.	No control start/finish of GT Process routes. No E-Papers	Dashboard to control start/finish GT Process. E-Papers on GT Process.		✔	✔

Figure 11 - Relationship between the different business process and key performance indicators.

2.6 Business requirements

Business objective: Connected Resilient Logistics Design and Planning.

No.	REQUIREMENT *Provide a short description of the requirement*	AREA[1]	SUB HEADING[2]	FUNCTIONALITY[3]	PRIORITY[4]
1	The logistics planning team should have autonomous planning tools.	Logistics	User	Functional	Critical
2	The logistics planning team should have better design tools in order to extract optimum solutions for the logistics processes.	Logistics	Performance	Non-functional	Critical
3	Adjustments to the logistics processes must be achievable quicker.	Logistics	Performance	Functional	Critical
4	Digitalization and communication between the systems throughout the logistics processes in the shopfloor.	Others (IT)	Support	Non-Functional	Critical
5	All data collected and/or processed must remain stored at local premises.	Others (IT)	Support	Non-functional	Preferred
6	Monthly updates to the system configuration should be implemented and supported with reporting highlighting changes and their financial savings.	Logistics	Reporting	Functional	Preferred
7	Reliable transport of material to the assembly line.	Logistics	Performance	Functional	Preferred
8	Simulation of optimal scenario for the GT Process and its resource occupation (line feeding assets) must be evaluated on a monthly basis.	Logistics	Performance	Non-Functional	Preferred
9	Subsequent updates to the GT Process must be considered and disseminated within the logistics service provider organizational structure.	Others (Logistics Service Provider)	Reporting	Functional	Preferred

GLOSSARY:

1 – Indicate to which area the requirement is addressed to:

Management
Marketing
Production
Production Control
Financial
Quality Control
Logistics
Human Resources
Sales & Purchases
Maintenance
Others: (Indicate)

2 – Choose the adequate from the following list:

User Requirements
Technical Requirements
Infrastructure Requirements
Reporting Requirements
Access Requirements
Security Requirements
Privacy Requirements
Performance Requirements
Support Requirements
Others: (Indicate)

3 – Choose one of the following:

- Functional Requirements: These describe how a solution should function from an end user´s perspective. They describe the features and functions of the system required by the user.
- Non-Fuctional Requirements: These describe the operational characteristic of the system. These could relate to availability, accessibility, performance, scalability, auditability, etc.

4 – Choose the adequate from the following list:

Critical	This are those types of requirements without which the business objective are achievable
Preferred	This requirements are those without which, the business objectives are achievable but not in the most efficient and effective way.
Optional	This requirements although desired do not affect the business objective defined.

2.7 System requirements

ID			SR-VWAE-1
Business requirement reference			BP1, BP3
Overall Description			Big Data Extract transform load (ETL)
Rationale			There is a need to integrate data from multiple different data sources to apply analytical models and tools.
Specific Requirements	*Feature*	*Introduction & Purpose of feature*	This service is responsible for handling data coming from heterogeneous data sources. Cleaning and harmonization processes will be implemented to ensure data veracity and quality, before or after storing it into appropriate data storages, capable of loading and providing large volumes of data. It also provides the function to save and schedule workflows and to enable automation of important tasks.
	Feature	*Stimulus Response Sequence*	Input: Legacy systems within VWAE, other relevant data sources; Output: Harmonized, cleaned, integrated data
	Feature	*Functional Requirements*	Extracts large volumes of data from heterogeneous sources; Harmonizes, cleans and integrates large varieties of data, before and after storage;
	External Interface Requirements	*User Interfaces*	Data Analytics Visualization environment UI and Superset UI
	External Interface Requirements	*Hardware Interfaces*	N.A
	External Interface Requirements	*Software Interfaces*	Big Data Collectors and Processors (Apache Kafka, Spark) Big Data Processing engines (Apache Spark) Big Data Storage (HDFS, MongoDb, Postgresql, MinIO, MSsql)
	External Interface Requirements	*Communications Interfaces*	
	Performance Requirements		1. Able to handle large volumes of data (in the order of TBs)
	Other non-functional requirements		Security, the data access must be secure.

ID			SR-VWAE-2
Business requirement reference			BP1, BP3
Overall Description			Big Data Processing Analytics Service.
Rationale			Clean and harmonized data permits the application analytics, machine learning models.
Specific Requirements	*Feature*	*Introduction & Purpose of feature*	This service is responsible for processing and performing Data Analytics over large volumes of data. Besides several algorithms already implemented by integrated tools other algorithms may be added via python.
		Stimulus Response Sequence	Input: Harmonized, cleaned, integrated data; Output: Insight data and knowledge in the form of Machine Learning, Data Mining and Analytics processes' results
		Functional Requirements	
	External Interface Requirements	*User Interfaces*	Specify the characteristics of each interface between the software and its users
		Hardware Interfaces	N.A.
		Software Interfaces	Big Data Collectors and Processors (Apache Kafka, Spark) AI toolkits (Keras, Tensorflow, Sklearn).
		Communications Interfaces	N.A.
	Performance Requirements		Able to handle large volumes of data (in the order of TBs)
	Other non-functional requirements		Security, the data access must be secure.

ID			SR-VWAE-3
Business requirement reference			BP1, BP3
Overall Description			Big Data Visualization & Querying Services
Rationale			There is a need visualize multiple different diverse data sources
Specific Requirements	*Feature*	*Introduction & Purpose of feature*	This service will provide the means for human users to visualize, assess, query and analyse large volumes of data, using user-friendly interfaces and well-known SQL commands.
		Stimulus Response Sequence	Input: Data coming from the Big Data ETL and Processing & Analytics services; Output: Data Visualization and Querying user interfaces
		Functional Requirements	1. Delivers Big Data Visualization tools in order to study and analyse the data coming from the ETL and Processing & Analytics services; 2. Enables efficient SQL queries on Big Data
	External Interface Requirements	*User Interfaces*	Apache Superset UI
		Hardware Interfaces	N.A.
		Software Interfaces	Apache Superset, Apache Druid
		Communications Interfaces	N.A.
	Performance Requirements		Able to handle large volumes of data (in the order of TBs)
	Other non-functional requirements		Scalability, Reliability, Modularity, Distributed, User-friendliness

2.8 Data Sources and Data Characterization

- ERP (VWAE)
  - Consumption of the part numbers (weekly) KBM
  - Call outs of the line BMA & iTLS
  - Location of the part numbers in the Warehouse LOGIS LOAD
  - Type of containers LISON
- Historical Data
  - Real Time Location System (twice per second) RTLS
  - Atual Production FIS

- Simulation tool (ASSECO-CEIT) — TWISERION
- Plant Layout (VWAE) — HLS
- Part number position in the Assembly line (VWAE) — BMA

Data Source Name			KBM
Type			
Licence			N/A
Data Owner			Volkswagen Group
Internal/External			Internal and Confidential
Details	*APIs*		Web based GUI
	Data	*Description*	• Demand of each part number per week
		Format	.csv
Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralized
	Volume (size)		High
	Velocity (e.g. real time)		Very Low
	Variety (multiple datasets, mashup)		High
	Variability (rate of change)		Very Low
Other Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*		Very High
	Visualization		Yes. Dashboard developed internally via Qlik Sense.
	Data Analytics		Yes. Dashboard developed internally via Qlik Sense.

Data Source Name			BMA
Type			Database, OPC, etc.
Licence			N/A
Data Owner			Volkswagen Autoeuropa
Internal/External			Internal
Details	*APIs*		
	Data	*Description*	• Location of part numbers in relation to the point of fit in the production areas
		Format	
Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralized
	Volume (size)		High
	Velocity (e.g. real time)		Very High
	Variety (multiple datasets, mashup)		Medium
	Variability (rate of change)		Very High
Other Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*		Very High
	Visualization		Yes. Business Intelligence tools with reporting developed internally/externally.
	Data Analytics		Yes. Business Intelligence tools with reporting developed internally/externally.

Data Source Name			LOGIS LOAD
Type			
Licence			N/A
Data Owner			Volkswagen Autoeuropa
Internal/External			Internal
Details	*APIs*		
	Data	*Description*	• Information about the location of the part number in relation to the warehouse
		Format	
Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralized
	Volume (size)		Medium
	Velocity (e.g. real time)		Medium
	Variety (multiple datasets, mashup)		Medium
	Variability (rate of change)		Medium
Other Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*		High
	Visualization		Yes. Business Intelligence tools with reporting developed internally/externally
	Data Analytics		Yes. Business Intelligence tools with reporting developed internally/externally

Data Source Name			iTLS
Type			
Licence			N/A
Data Owner			Volkswagen Autoeuropa
Internal/External			Internal
Details	*APIs*		
	Data	*Description*	• Information about the transport of material from warehouse to production areas
		Format	
Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralized
	Volume (size)		High
	Velocity (e.g. real time)		High
	Variety (multiple datasets, mashup)		Medium
	Variability (rate of change)		High
Other Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*		High
	Visualization		Yes. Business Intelligence tools with reporting developed internally/externally
	Data Analytics		Yes. Business Intelligence tools with reporting developed internally/externally

Data Source Name			LISON
Type			
Licence			N/A
Data Owner			Volkswagen Group
Internal/External			Internal
Details	*APIs*		
	Data	*Description*	• Information about containers types and part quantities per part number
		Format	
Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralized
	Volume (size)		Low
	Velocity (e.g. real time)		Very Low
	Variety (multiple datasets, mashup)		Medium
	Variability (rate of change)		Low
Other Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*		High
	Visualization		Yes. Dashboard developed internally via Qlik Sense.
	Data Analytics		Yes. Dashboard developed internally via Qlik Sense.

Data Source Name			RTLS
Type			Database
Licence			Yes
Data Owner			Volkswagen Autoeuropa
Internal/External			
Details	*APIs*		SQL data access
	Data	*Description*	• Line Feeding Asset Coordinates
		Format	.csv.
Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralized
	Volume (size)		Very High
	Velocity (e.g. real time)		Very High
	Variety (multiple datasets, mashup)		Low
	Variability (rate of change)		Very High
Other Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*		High
	Visualization		Yes. Visualization achievable through dedicated software developed by provider of solution.
	Data Analytics		No. Dashboard nor Software have been developed for this purpose.

Data Source Name			FIS
Type			Database
Licence			N/A
Data Owner			Volkswagen Group
Internal/External			Internal
Details	*APIs*		SQL data access
	Data	*Description*	• Production data
		Format	
Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralized
	Volume (size)		Very High
	Velocity (e.g. real time)		Very High
	Variety (multiple datasets, mashup)		Very High
	Variability (rate of change)		Very High
Other Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*		Very High
	Visualization		Yes. Multiple dashboards and software's are available.
	Data Analytics		Yes. Multiple dashboards and software's are available.

Data Source Name			HLS
Type			Database, OPC, etc.
Licence			
Data Owner			Volkswagen Group
Internal/External			Internal
Details	*APIs*		
	Data	*Description*	• System with CAD drawing regards plant's infrastructure.
		Format	
Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralized
	Volume (size)		High
	Velocity (e.g. real time)		High
	Variety (multiple datasets, mashup)		Low
	Variability (rate of change)		Medium
Other Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*		High
	Visualization		N/A
	Data Analytics		N/A

3 AVL Pilot

3.1 Use-case sequence

The AVL pilot based for the development of the RE4DY project is a flexible centre for production-oriented manufacturing of prototype battery modules and packs (Figure 13¡Error! No se le ha dado un nombre al marcador.). The characteristics of this manufacturing centre are:

- Assembly process development for specific assembly procedures in battery production
- Close-loop feedback to product development (DfM - Design for manufacturing)
- Serve higher volumes in A- & B-sample prototypes
- Provide capacity for field test fleets, racing series and C-samples
- Provide industrialized designs and processes "ready for ramp-up"
- Leveraging of engineering business for battery development
- Verify Eco-Design products in respect to recycling and cost
- Fusion of Function & Process Development

Figure 12: Overview of the AVL pilot in RE4DY project.

The Battery Innovation Center (BIC) was created with the aim of being able to work out for the first time both battery modules and an energy-efficient production or recycling process for battery modules and to optimize and validate them in a near-series environment. All common core processes of battery module production can be demonstrated at fully automated stations. Regardless of cell type, cell voltage and degree of integration, all steps of module production can be mapped. With the industrial robots in the BIC, AVL can also serve the battery development goals of "cell-to-body" and "module-to-chassis", which are becoming increasingly important for car manufacturers. Another important innovation of the BIC is the production-technical safeguarding of large-scale production in a real industrial environment. In the pilot line, the production process designed simultaneously during module development can be tested in detail under real conditions. In this way, battery modules can be manufactured in the BIC from individual production at A-sample level to construction batches of several hundred pieces under complete monitoring of defined quality characteristics.

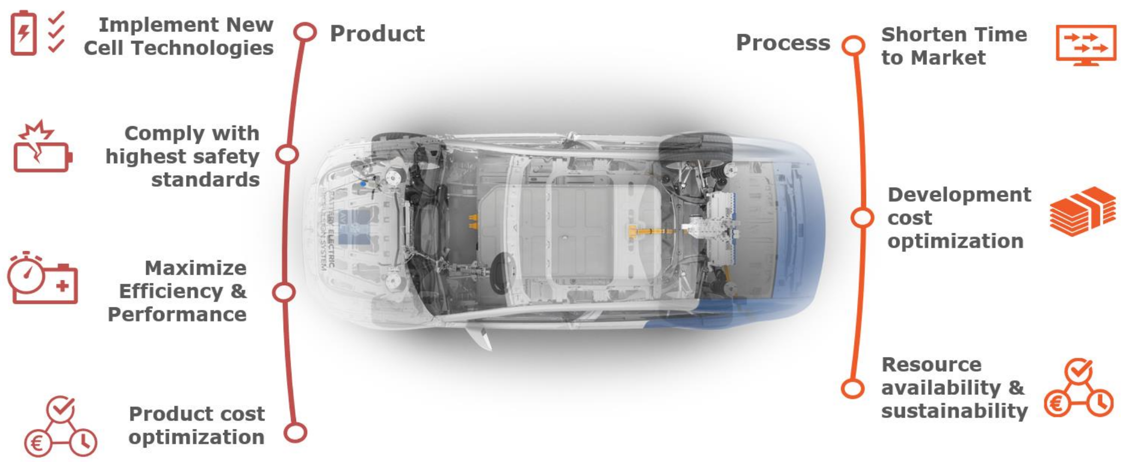


Figure 13: Battery system technology & process challenges

In the use-case scenario Visual Components and Fill are techprovider for AVL as a TIER-1 in battery system technology & process design.

The development of the 3D simulation and visualization within Visual Components follows a workflow from concept to deployment using the process modelling simulation feature.

The Process Modelling workflow was designed to resemble how real-world production design is done in practice. It consists of the following 5 steps:

1. Layout design.
2. Define products, their visualization, structure and properties.
3. Define processes, like machines, workstations, inventories and buffers using task statements.
4. Define flow by creating sequences of processes that products must complete.
5. Run the simulation, collect KPIs, make necessary changes to achieve your goals.

1. Layout design

The first step in the workflow is to design or configure the physical layout of the production system. This can be created using simulation-ready components from the eCatalog and/or CAD data, which you can import directly into the software. Equipment should be placed in the correct position and orientation, and stations, walkways, buffers, fixtures, and spacing requirements should all be factored into the design.

For this phase Fill is the tech provider that creates layouts for production equipment based on standardized components as industrial robots, conveyors and devices designed for the production of the products. The production cells are equipped by standardized safety fences, electrical installation and cabinets.

2. Define products

A Product is an entity that goes through a certain process in a layout. In the use case it is a module of batteries. Products that undergo processes can be defined in this phase. From the Product Type Editor, engineers of AVL are able to configure and manage the following:

- Product flow group; which is the collection of product types sharing the same production flow sequence. In this use case it is the production of pouch cells that are stacked to a module in the BIC, battery innovation center.
- Product type name; this can be a short description of the product like cylinder, car tire, motor plate, etc. In this case, the product is a battery module.
- Product properties; these can include parameters like dimensions, weight, material, etc. In the use case it is the stack of different shaped batteries in different amount within the stack.
- 3D product geometry; a 3D geometry can be imported and selected as a product like in this example, the battery module is an external CAD file. The designer of AVL can change the dimensions and the process simulation can be run and checked if there are limits of dimensional changes that will cause a reconfiguration of the production equipment.

3. Define processes:

A process is a representation of a machine, work phase, inventory, buffer or some other production step. In Process Modelling, a Process is expressed as a set of statements, which assign certain behaviours to a product. Processes are built from statements using the Process Editor. With routines and statements, machines, especially industrial robots, can be configured to behave like their real-life counterparts, such as machine doors opening and closing, processing times, product geometries changing with processes, parts attachment, and so forth.

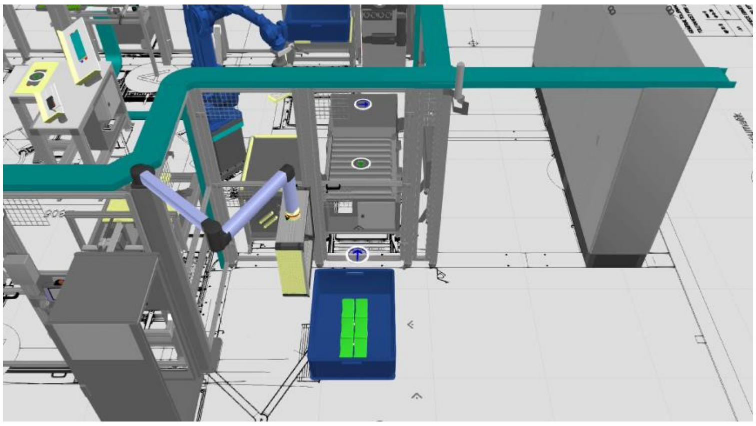
Before defining processes, it's important to consider how products should evolve during production. In the use case, the products undergo different processes.

4. Define Flow

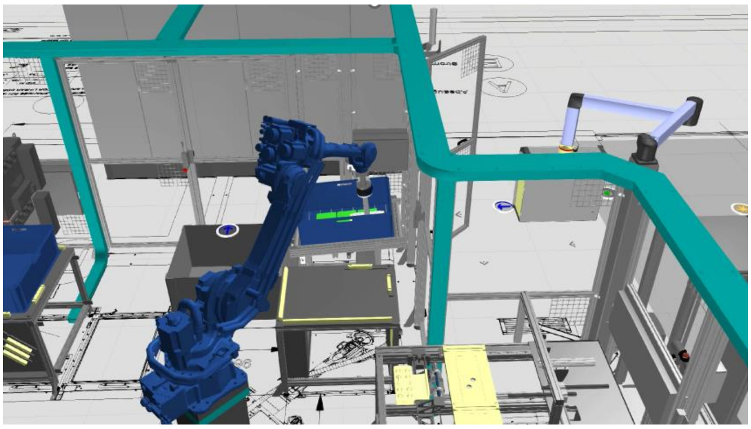
A flow is the sequence of processes that products follow in a production system. In process modelling, products are defined in groups based on the path they follow during the simulation. These groups are called flow groups. Using the Process Flow Editor, engineers are able to define flow groups and the production flow for each product. It is also possible to define the transport links, which determine how products are transported between two processes during the simulation, this is not connected to the CAD of the product, it is connected to the process itself. A resource, such as a human, industrial robot or AGV can be assigned to each transport link, which then transports products based on its capabilities.

In the use case, the BIC production cell is defined. The process is covering:

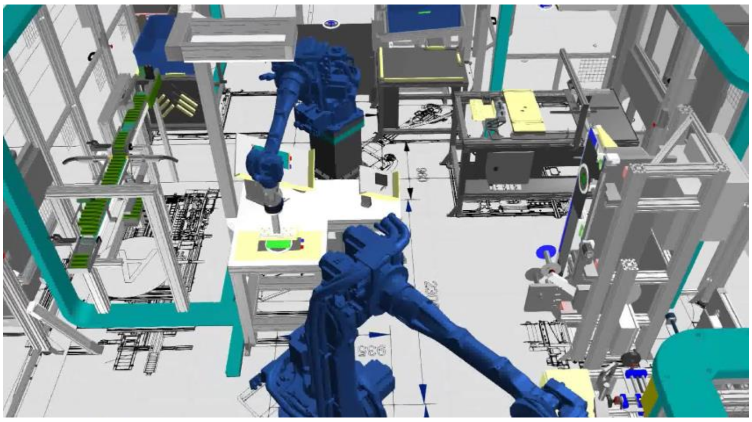
- First, a source to bring in the products into the system is designed, this is done by AGV out of an eCatalog.



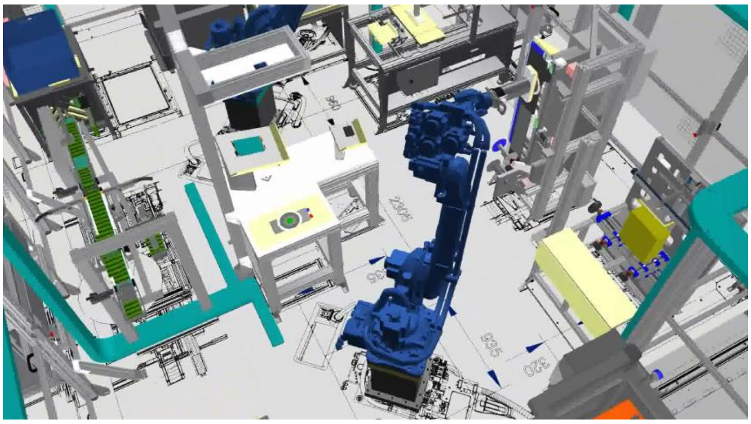
- The first process is an industrial robot as a picking station.



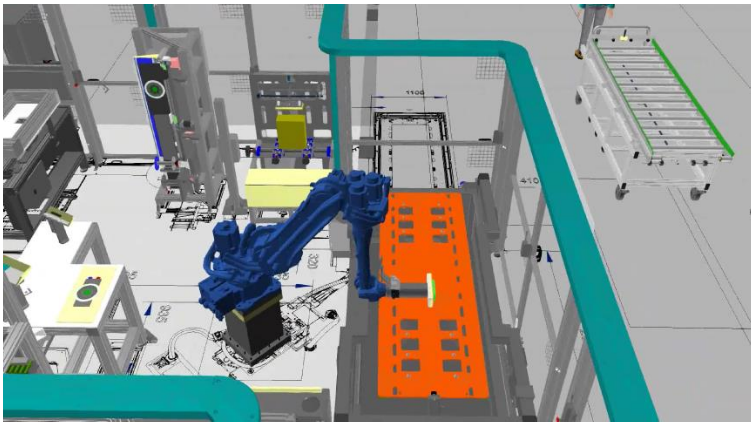
- Next, the quality checking station:



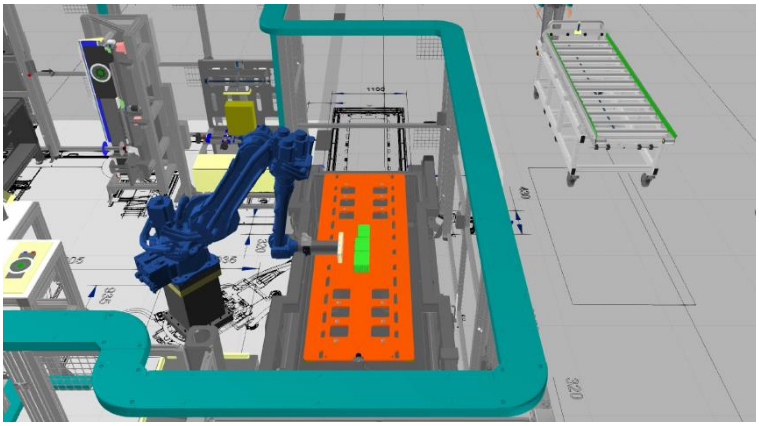
- The next step overtakes an other industrial robot



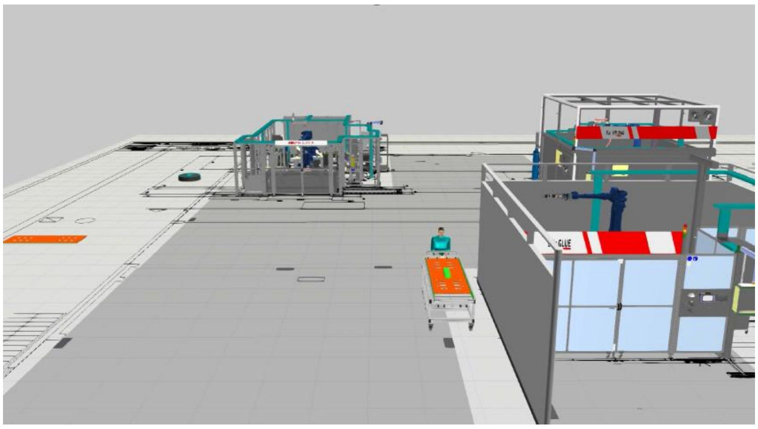
- After the cells are checked they are stacked to be welded.



- After stacking the module is picked up by a manual transport device.



- Then the stack is brought to the next production cell.

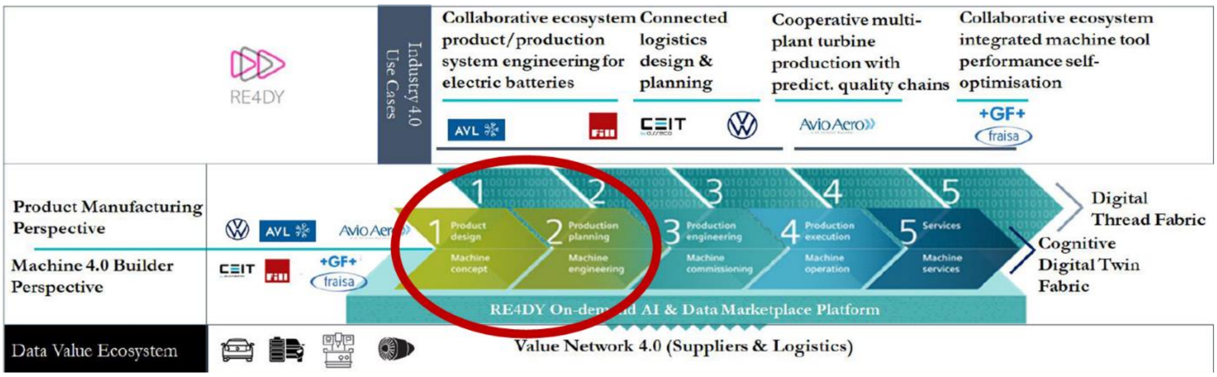


5. Run Simulation

When the simulation model is set up, it's ready for simulation. Basic multimedia controls can be used to play the simulations, collect KPIs, make modifications, and export in a variety of formats.

3.1.1 PoC definition

To realize the set objectives, different business processes are set up and are investigated to proof the benefits for the digital continuity in the production process from product design to the manufactured product. In the project Re4dy the use case is specified as "collaborative ecosystem product/production system engineering for electric batteries from the point of view of the product manufacturing perspective in this case AVL and the machine 4.0 builder perspective represented by Fill. Visual components is the tech provider for implementing the cognitive digital twin fabric.



The objectives for the end user pilot (AVL) are in line with the targets of the project:

- O1: Establish a resilient manufacturing engineering reference framework for digital smart products & production value ecosystems in connected factories 4.0

  Developing a general model for jointly optimizing individual and value chain industrial process efficiency, sustainability and reliability.

- O2: Increase big data pipelines, data, digital thread and digital twin autonomy and interoperability with a set of open Digital 4.0 continuum toolkits for value networks of "Data as a Product"

  Integrating the distributed data management operations and increase data and pipeline reusability and portability.

- O3: Accelerate and reduce implementation costs of integrated intelligence and active knowledge in holistic cognitive & collaborative connected factory 4.0 Zero X smart manufacturing

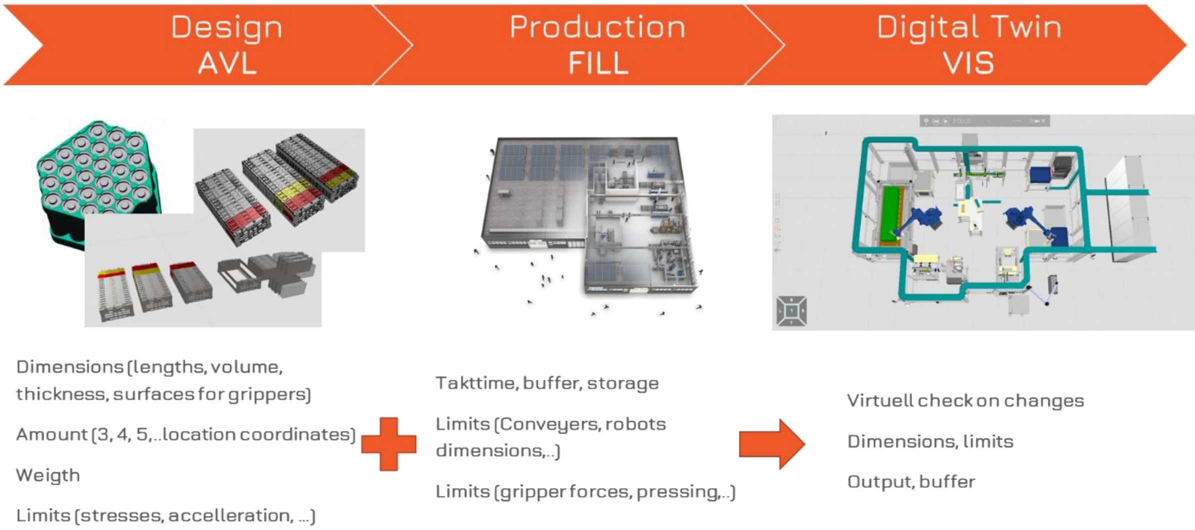
  Increasing efficiency, scale and trust building in distribute d Industrial Internet value networks set up & data sharing

- O5: Democratize industrial data spaces and cognitive digital twins maximizing commercial impact, optimizing up/re skilling needs and adoption (manufacturing and digital)

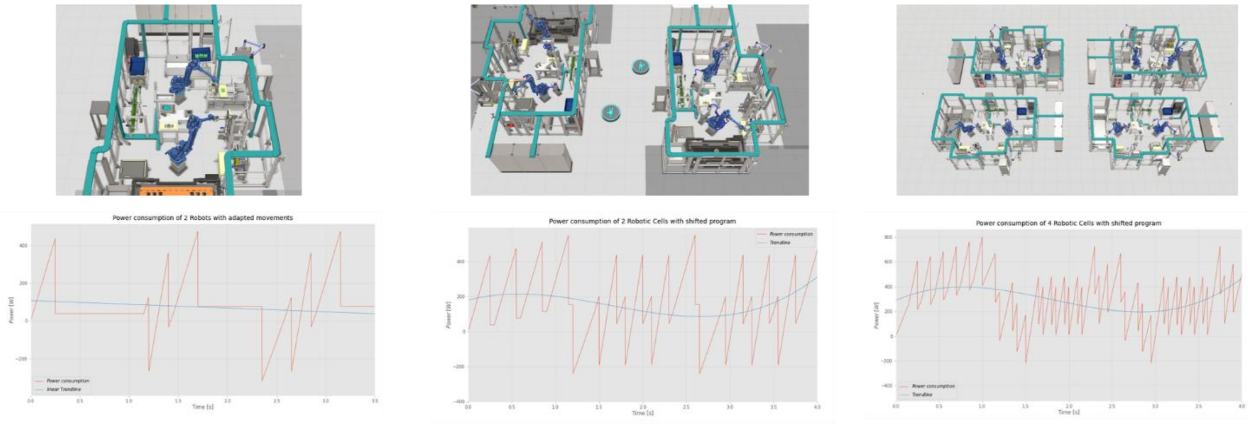
  Identifying access to data sets and support to build resilient DT processes and become trusted value network prosumers.

3.1.2 First experimentation results

The implementation of the defined process in a first prototype version is done, and the investigation of the business processes is started. The following figure is showing the process. The product changes of battery modules by the designer AVL e.g. in dimensions is done in the CAD. In the next step the designed production layout, which is also available in CAD, by Fill is checking the needed changes due to the product changes. As an example the width of the module can be easily checked if the gripper of the industrial robot is capable in dimensions, forces and the industrial robot can handle the weight. Also limits concerning accelerations and velocities are defined. This is important to check the time related changes due to the product changes, e.g. the stacking time increase because of 4 batches instead of 3 batches and its overall impact on takttime and OEE related changes. This cognitive digital twin is set up on the simulation tool by Visual Components. With this tool further optimization can be investigated as further described in the business processes.



The below figure is showing the production cell described and the analytics of the energy consumption of the robots. By scaling up to a production facility to run several cells the over all energy consumption can be estimated. By synchronizing the cells, the maximum energy consumption is defined, by orchestration of the robots movements in a way that the recuperation of the braking energy can be used for acceleration of another robot the maximum current peak of electricity from the net can be reduced.



Production Cell arranged

Factory movement arranged

By adding further parameters to the simulation models a multi-disciplinary optimization (MDO) can be set up this will include additional value streams.

3.2BP Business Process overview

Four business processes are identified. The brief description in given in the following section. There are several connections in between the business processes and an increase in one will cause dependencies in the others. The digital continuity of data of the product and the production process is mandatory and opens up the full potential of digitalization and optimization. While BP1 Agility is focusing on the quick adaption on product changes, speed to market and time saving for new solutions, BP2 Sustainability is investigating the connected production resources needed and the optimization on them. BP2 also includes SDGs e.g. 8 for decent work and 9 industry. BP3 Customization meets the needs of OEMs for customisation. BP4 Productivity OEE is the all time relevant business process for over all equipment effectiveness (OEE) which is the most important KPI of availability x performance x quality rate.

BP 1 – Agility

- Agility – Time to adapt to product change reduction (-30%)
- Speed to market – Lot-size-1 engineering (-15%)
- Less time designing new solutions (-10..15%)

BP 2 – Sustainability

- Sustainability – Energy and resource efficiency increase (15%)
- Connect smart factory
  - Efficient connection of machines line
- Safety of workers
  - Zero emissions, zero overwork, zero injuries

BP 3 – Customisaton

- Customisation – Battery package optimizations (+10..15%)

BP 4 – Productivity OEE

- Availability – Unplanned downtime reduction (-20%),
- Service cost reduction (-15%)

Figure 14: business processes overview

As an independent service provider in battery technology, AVL offers a full package of innovative tailored solutions to address the challenge of clean e-mobility. Their dedicated products and services cover the entire battery development process – from the assessment and selection of a single cell to SOP of a fully validated battery packs. Mechanical and thermal pack integration into the vehicle feature with low cost design, performance, serviceability, energy efficiency and recyclability.

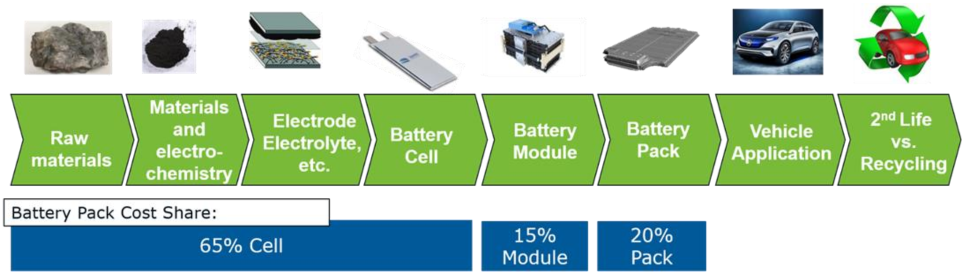


Figure 15: manufacturing and production process steps of battery systems for e-mobility

Currently AVL has only a small market share compared to the whole market share available in the battery value chain. The focus lies on the module, pack and vehicle application, not from manufacturing perspective but from engineering service provider perspective. In that case the market share is relatively small compared to competitors which are focusing on manufacturing topics.

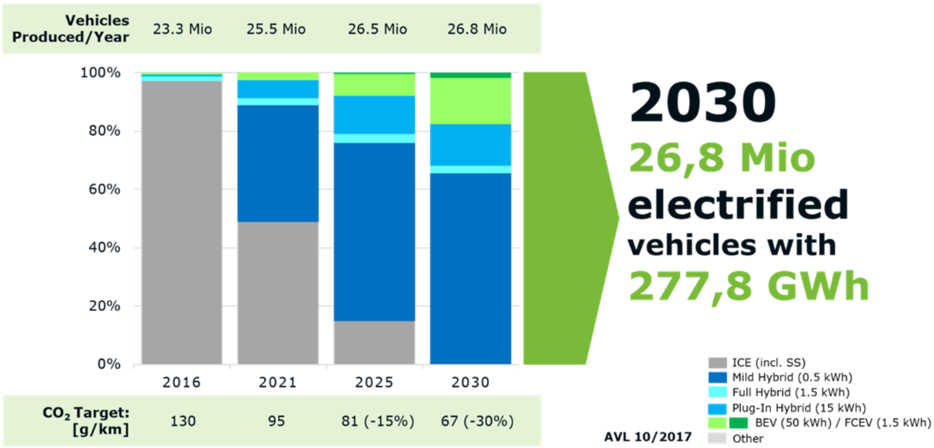


Figure 16: developing of e-mobility shares in automotive industry

The AVL prediction for the vehicle share in Europe till 2030 can be seen. As it can be seen, till 2030 26,8 million vehicles will be electrified and the need for traction battery solutions will increase dramatically. Therefore, AVL wants to be prepared to be a part of the battery value chain and use the opportunity to grow with the increasing market.

On the one hand AVL is providing prototype manufacturing and process development for their customers as well as on the other hand AVL will perform production and plant planning for the series production of the OEM. During the product development process and the production planning process the overall IT solutions like data share over the values chain will be analyzed and developed to guaranty the traceability and product quality.

3.2.1 Business process in detail

Agility:

For the present factory scenario, machine lines are built to process and produce parts and goods within a minimum of time and sources. The machine process chain, consisting of several single process steps, specifically connected to each other, is fully optimized. As a characteristic of a fully optimized process chain, it is difficult and requires much effort to change any parameters without the risk to lower the quality or the speed of the machine output. Changes of parameters or machine parts lead to unknown or unexpected changes to the process.

Using a fully machine simulation digital twin, it is possible to change the process parameter and check how this influences the machine process and the output of the machine prior to physical, real changes. Therefore the risk to have any unexpected influences to the process is lowered to a minimum, which improves the ability to adopt and change the machine process, thus the agility of the system by at least 30%. Risk due to reduced output or quality of parts or unexpected machine downtimes would lead to loss of production capability, therefore lead to rising of costs and loss of money.

3.2.2 Business indicators

An overview of all business indicators is given in the table 2 Business Indicators. For BP1 Agility the related indicators are:

- Agility – Time to adapt to product change reduction (-30%)
- Speed to market – Lot-size-1 engineering (-15%)
- Less time designing new solutions (-10..15%)

3.2.3 Business requirements

Summed up in 3.5.3.

3.3 BP2 - Sustainability

3.3.1 Business process in detail

Sustainability:

For the present scenario, it takes much time to ramp up a machine process till it is in equilibrium production state. In this ramp-up phase a lot of production scrap is generated, which cannot be used due to poor quality of the parts. This is even more true in case of total new and unknown processes.

By using digital twin and process simulation, the ramp-up phase can be reduced by minimum of 20%, therefore it is possible to save 20% of NIO parts during the development of a new process or ramp-up phase of a machine, which means a reduction of costs, sources and time for the end-user of the machine. The impact to the sustainability is therefore high.

3.3.2 Business indicators

- Sustainability – Energy and resource efficiency increase (15%)
- Connect smart factory
  - Efficient connection of machines line
- Safety of workers
  - Zero emissions, zero overwork, zero injuries

3.3.3 Business requirements

Summed up in 3.5.3.

3.4 BP3 - Customization

3.4.1 Business process in detail

Customisation:

For the present scenario customization towards customer specific desires is difficult to handle without adding a lot of effort, time and costs to the customer. As changes and

adoption to series processes or already developed machine concepts might lead to downtime of machine and unknown machine output influences, customer wishes and customisation might be neglected or reduced to a minimum to keep these risks at a low level.
BY using the digital twin and machine data simulation of the changed/customized machine process due to customer wishes and changes, it is possible to check, whether these customization and changes can be dealt with at all (or it is impossible to implement) and if these can be implemented, how these will influence the machine process chain and output behaviour of the machine. After checking these result, the wished customization and the connected influences to the machine concept might lead to unwanted output or quality reduction, and customization might be neglected or removed prior to any machine concept changes. This will avoid unexpected costs due to unnecessary hardware changes for future customer ideas. The potential of realization of customer customization can be increased by 15% in future machine concepts.

3.4.2 Business indicators

- Customisation – Battery package optimizations (+10..15%)

3.4.3 Business requirements

Summed up in 3.5.3

3.5 BP3 – Productivity OEE

3.5.1 Business process in detail

Productivity:
For the present scenario, machine concepts are developed by history data and machine and process experience from the past. The process parameters are often based on similar machines, already built and installed at other places. For a series machine, running 24h/7day a week, it is of big importance to increase the productivity to the maximum possible. Each increase of productivity will lead to higher machine output, therefore the machine line efficiency is higher, the output is higher and even the quality might still be increased by optimisation. At a specific degree changes to machine concepts become difficult to predict and optimisation processed might be stopped at a specific level to avoid an over-engineering and over-optimisation, which often lead to a reduction of productivity instead of an improvement. Using process simulation data of digital twin can help to increase the productivity of machine lines, although they are assumed to be fully optimized. As further optimization leads to a still better result in simulation and digital twin results, these optimizations can be realized in hardware at the existing machine. It is assumed that the productivity of an already optimised machine can still be increased by 10% to the present productivity potential of machines. This significantly strengthens the market potential of Fill machines.

3.5.2 Business indicators

Table 1: Business Indicators

ID	BUSINESS Indicators *List the Business objectives expected for the Business Scenario/Use Case*	DESCRIPTION *Give a detailed description of the indicators*	Unit*	Current value	Future expected value	Expected date of achievement **
1	O1.1	lot-size-1 engineering lead time	Hours	N/A	-15% of Start-Value	+12 months
2	O1.1	reducing failures due to design faults	Number of faults	N/A	-15% of Start-Value	+12 months
3	O1.2	Identification of components for pattern and anomaly detection	Number of Components	0	at least 2 components of a machine tool	+12 months
4	O1.2	Identification of behaviours for each component, which we want to analyse and detect	Number of behaviour	0	At least 1 behaviour for each component, which we want to analyse and detect	+6 months
5	O1.2	implemented and tested pattern and anomaly detection (framework and algorithms)	N/A	no pattern and anomaly detection framework	implemented and tested pattern and anomaly detection	+12 months
6	O1.3	Synchronizing model- and data driven information	Data volume in bytes	Is still increasing through technology	Near real-time data analysis from big data	+12 months

3.5.3 Business requirements

The business requirements defined for the business processes and the use case scenario to define what the business wants the implementation to do, to be used in the following table.

No.	BUSINESS OBJECTIVE	REQUIREMENT *Provide a short description of the requirement*	AREA[1]	SUB HEADING[2]	FUNCTIONALITY[3]	PRIORITY[4]
1	O1.1	Digital continuity of CAE data of product & production process to design a cognitive digtial twin	Production, others: engineering	Technical requirments	Functional	critical
2	O1.1	Using results from data analytics from production process for reducing failures	Production control	Performance requirments	functional	critical
3	O1.1	Executing co-simulation with diffrent behavior models including data analytics	Quality control	Reporting requirements	functional	preferred
4	O1.2	Identification of components for pattern and anomaly detection and support commissioning and increase resiliency of production process	Production, production control	Performance requirements	functional	preferred
5	O1.3	Digital cognitve twin of manufacturing process and production equipment for real time analytics and investigation on failures and failure dependencies	Production	Infrastructure requirments	functional	preferred
6	O1.1	Product changes check with the digital cognitive twin, changes that only need reprogramming, changes that need reconfiguration as minor adaption and changes that need replacements due to limits (e.g. payload of robots)	Production	Infrastructure requirments	functional	critical
7	O1.2	Production equipments health status, identification of critical status of components with data analytics of historical data and models. (e.g. control time of PLC relation to	Production	Technical requirments	functional	preferred

		wear of gear or spindel drives)				
8	01.3	Synchronizing model- and data driven information out of production process with product in use information and supporting the digital product pass	Manageme nt	Reporting requirments	functiona l	critical
9	01.2	Optimisation tool for production equipment to reduce resources and energy	Manageme nt	Technical requirments	functiona l	preferred
10	01.1	Commissioning and integration of the developed interfaces, standards, devices and services into customers infrastructure (in the project in BIC – Battery Innovation Center of AVL)	Manageme nt	Technical requirments	functiona l	preferred

Extended to the table above the involved actors and their impact are summed up.

ACTOR *(Blue Collar Workers, Manager, Coordinator, clients, provider, etc.)*	BUSINESS AREA *(marketing, administration, manufacturing, etc.)*[1]	TYPE OF IMPACT (Direct or Indirect)	DESCRIPTION OF THE IMPACT *Detail the expected impact of the Business Scenario/Use Case for each actor in their Business Area*
Engineeringmgt. Administrator	Administration	Direct	Implementation and administration of new processes and tools
Senior Engineer	Pre-Engineering, System-Engineering	Indirect	Using Results from Big Data Analysis; Using Results from Digital Twin Simulations; Consideration of IoT and Big Data solutions in the concept design of production systems.
Engineer	Mech. Engineering	Direct/Indirect	Executing co-simulations with different behavior models including big data analytics; Increased use of verified data (model- and data driven approaches)
Engineer	Softw. Engineering	Direct/Indirect	Executing co-simulations with different behavior models including big data analytics; Increased use of verified data (model- and data driven approaches)

Engineer	Elekt. Engineering	Direct/Indirect	Executing co-simulations with different behavior models including big data analytics; Increased use of verified data (model- and data driven approaches)
Engineer	IoT Engineering	Direct	Completely new business area; Design and Implementation of IoT and Big Data solutions
Engineer	Data Engineer	Direct	Design and implementation of Big data platform, IDS connector, etc.
Engineer	Data Scientist	Direct	Completely new business area; Design and Implementation of IoT and Big Data solutions
Application Engineer	Inhous-commissioning	Direct	Using and commissioning of the developed interfaces, standards, devices and services
Application Engineer	Commissioning	Direct	Commissioning and integration of the developed interfaces, standards, devices and services into the customers infrastructure

3.6 System requirements

Following data sources have been identified and are the basis for the use case scenario and its business processes. The characterization is updated during implementation.

Data Source Name			CAD Models DB from the product
Type			Database of CAD models
License			PTC Inc. Windchill
Data Owner			AVL
Internal/External data			Internal data
Details	*APIs*		Data exchange of CAD file server
	Data	*Description*	Bill of materials Products
		Format	.STL, .IGS, .IGES, .PRT, .x_t, .asm, .prt, .xas, .xpr
Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralized CAD server
	Volume (size)		GB
	Velocity (e.g. real time)		Versionized real time
	Variety (multiple datasets, mashup)		Multple datasets
	Variability (rate of change)		hourly/daily/weekly/monthly
Other Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*		Changing quality in meta data
	Visualization		3D model viewer
	Data Analytics		n/a

Data Source Name			CAD Models from the simulation/ digital twin
Type			Database (eCat) of simulation models
License			Visual Components Oy
Data Owner			Visual Components, System provider (FILL, AVL), Customer (AVL, end-customer)
Internal/External data			Internal data
Details	*APIs*		Data exchange of CAD file server
	Data	*Description*	Bill of materials, Products CAD
		Format	Most of the commercial CAD formats (import). Simulation/DT: .vcm, .vcmx. 3d/VR visualization: .vcax
Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralized CAD file server
	Volume (size)		GB
	Velocity (e.g. real time)		Versionized real time
	Variety (multiple datasets, mashup)		Multiple datasets
	Variability (rate of change)		hourly/daily/weekly/monthly
Other Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*		Changing quality in meta data
	Visualization		3D graphic interface, 3D/VR viewer
	Data Analytics		Included analytics visualization, open interface to expose through TCP/IP, WebSocket, OPCUA, ad-hoc interface

Data Source Name			PLC & Robotics Data (AVL)
Type			Database.
License			SIEMENS TIA Portal
Data Owner			AVL
Internal/External data			Internal
Details	*APIs*		Server
	Data	*Description*	Program steps for different programs and processes
		Format	.TIA
Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		distributed
	Volume (size)		MB
	Velocity (e.g. real time)		Versionized real time
	Variety (multiple datasets, mashup)		Multiple datasets
	Variability (rate of change)		weekly
Other Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*		
	Visualization		N/A
	Data Analytics		Input for digital twin data analytics

Data Source Name			PLC (Simulation/DT)
Type			PLC program file
License			IEC 61131 (Standard), IEC 61499 (Standard), Proprietary (Siemens, Beckhoff)
Data Owner			Machine provider (FILL), Customer (AVL)
Internal/External data			Internal
Details	*APIs*		OPC-UA, TCP/IP, WebSocket, I/O signals
	Data	*Description*	Program statements for PLC program
		Format	XML, TXT, I/O signals
Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralized
	Volume (size)		MB
	Velocity (e.g. real time)		Next-to-realtime
	Variety (multiple datasets, mashup)		Multiple datasets (sensors, actuators,…)
	Variability (rate of change)		ms
Other Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*		N/A
	Visualization		N/A
	Data Analytics		Accessible with operation data based for analytics.

Data Source Name			Robot programing (Simulation/DT)
Type			Robot program file
License			Visual Components Oy (Robot program in Simulation/DT, and postprocessors). VRC Robot provider (Yaskawa, KUKA, UR,…)
Data Owner			Machine provider (FILL), Customer (AVL)
Internal/External data			Internal
Details	*APIs*		OPC-UA, TCP/IP, WebSocket, I/O signals, dedicated Robot connector (Yaskawa, KUKA, UR,…)
	Data	*Description*	Robot Program statements for robot program
		Format	XML, I/O signals, Proprietary
Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralized
	Volume (size)		MB
	Velocity (e.g. real time)		Next-to-realtime
	Variety (multiple datasets, mashup)		Multiple datasets (sensors, actuators,…)
	Variability (rate of change)		ms
Other Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*		N/A
	Visualization		N/A
	Data Analytics		Accessible with operation data based for analytics.

Data Source Name			Process Data (AVL) - Traceability Data
Type			Database Server
License			Microsoft SQL Express /MS SQL Server
Data Owner			AVL
Internal/External data			Internal data
Details	*APIs*		SQL express data access
	Data	*Description*	Serial numbers of components Process data Testing data Traceability data Production data
		Format	.XLSX, .CSV
Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		centralized
	Volume (size)		GB
	Velocity (e.g. real time)		Near real time
	Variety (multiple datasets, mashup)		Dataset for each battery cell
	Variability (rate of change)		Once finished no changes
Other Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*		
	Visualization		Power BI dashboards on AZURE cloud solution
	Data Analytics		Power BI dashboards on AZURE cloud solution

Data Source Name			Quality Assurance Data
Type			Database
License			Server
Data Owner			AVL
Internal/External data			Internal
Details	*APIs*		Server access
	Data	*Description*	Quality pictures for process control
		Format	.JPG, etc.
Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Production machine
	Volume (size)		GB
	Velocity (e.g. real time)		Real time
	Variety (multiple datasets, mashup)		Multiple datasets
	Variability (rate of change)		
Other Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*		
	Visualization		
	Data Analytics		

3.7 Data Sources and Data Characterization

The following data sources are identified and will contribute to the business processes in the AVL use case scenario on battery systems ecosystem. IoT is the data streamed out of the production system with data acquisition. CAD are the different available formats of the product components and the production equipment. Equipment is additional available data for production equipment beside CAD. Engineering is the data additional available to CAD and includes data used for model based definition and model based system engineering and covers CAE as simulation out of FEA Finite elements analysis and multibody dynamics, this data is often used in control. On top there is additional information available in software systems by the involved companies a long the supply chain. This data will extend data sets as it is relevant e.g. raw material and tolerances.

Type of data	Data Source	BP1	BP2	BP3	BP4
Internal Data	IoT	+	o	+	o
	CAD	++	o	++	+
	Equipment	++	+	++	+
	Engineering	++	++	+	o
	Corporate SW (ERP, MES…)	o	o	o	+
External Data	IoT	+	o	+	o
	Equipment	++	o	++	+
	Engineering	++	+	++	+
	Corporate SW (ERP, MES…)	o	o	o	+

The following data sources of the pilot are accessed. The BIC Battery Innovation Center at AVL and the developed cognitive digital twin in the software system of Visual Components. A more detailed characterization will be given 6 months after implementation.

Pilot Data Fiche	BIC	Digital Twin
Industrial Data Volume	Production data from real machines and plants, including also work orders	Simulation data, CAD Data, Training data and documents
Data Velocity (Gb/day)	50MB…3 Gbytes /16h shift depending on process and rate	Currently supports similar to real pilot that can be multiplied by parallel simulations
Data types	PLC, sensors, ERP	Currently supports similar to real pilot that can be multiplied by parallel simulations
Number of data sources	Scalable to the entire equipment in the cell	Currently supports similar to real pilot that can be multiplied by parallel simulations
Open data (Y/N)	No	No
Stakeholder Data Owner	Production owner, Pilot line owner	Machine builder, Technology provider, end user

4 Conclusions

D4.1 provided an in-depth overview of the pilots' setup, value network service design, and data preparation for "connected logistics for automotive" and "collaborative ecosystem SP2 for electric battery production." This deliverable was consolidated by an iterative process addressing in chapters 1, 2, and 3 of the THs. Future focus will be on scaling up the pilots and on-site validation using RE4DY's solutions, along with revising the KPI assessment.