Boost 4.0
BIG DATA FOR FACTORIES

Big Data Value Spaces for Competitiveness of European Connected Smart Factories 4.0

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Authors	Konstantinos Sispas – INTRA, Jesús Alonso - INNO
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Participant organisation name	Acronym
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Volkswagen Autoeuropa, Lda *	VWAE
Visual Components	VIS
Automatismos y Sistemas de Transporte Interno S.A.U.	ASTI
Telefónica Investigación y Desarrollo SA	TID
Volkswagen AG. *	VW
UNINOVA	UNINO
FILL GmbH. *	FILL
TTTECH Computertechnik AG	TTT
RISC Software GmbH	RISC
PHILIPS Consumer Lifestyle B.V. *	PCL
PHILIPS Electronics Nederland	PEN
Interuniversitair Micro-Electronicacentrum VZW	IMEC
Centro Ricerche Fiat S.C.p.A. *	CRF
SIEMENS S.p.A.	SIEMENS
Prima Industries S.p.A	PRIMA
Politecnico di Milano	POLIMI
AUTOTECH ENGINEERING, AIE *	GESTAMP
Fundació Privada I2CAT, Internet I Innovació Digital A Catalunyai2cat	I2CAT
TRIMEK S.A.	TRIMEK
CAPVIDIA N.V,	CAPVIDIA
Volvo Lastvagnar AB *	VOLVO
Chalmers Tekniska Hoegskola AB	CHAL
Whirlpool EMEA SpA *	WHIR
SAS Institute Srl	SAS
Benteler Automotive GmbH *	BAT
It.s OWL Clustermanagement	OWL
Fraunhofer Gesellschaft Zur Foerderung Der Angewandten Forschung E.V.	FhG
Atlantis Engineering	AE
Agie Charmilles New Technologies SA *	+GF+
Ecole Polytechnique Federale De Lausanne	EPFL
Institut Für Angewandte Systemtechnik Bremen GmbH	ATB
Rheinische Friedrich-Wilhelms-Universitat Bonn	UBO
Ethniko Kentro Erevnas Kai Technologikis Anaptyxis (CERTH)	CERTH
The University of Edinburgh	UED

Institute Mines Telecom	IMT
International Data Spaces e.V.	IDSA
FIWARE Foundation e.V	FF
GEIE ERCIM EEIG	ERCIM
IBM ISRAEL – Science and Technology LTD	IBM
ESI Group	ESI
Eneo Tecnología, S.L	ENEO
Software Quality Systems S.A.	SQS
Consultores de Automatización y Robótica S.A.	CARSA
INTRASOFT International	INTRA
United Technologies Research Centre Ireland, Ltd *	UTRC-I
Fratelli Piacenza S.p.A. *	PIA
RiaStone - Vista Alegre Atlantis SA *	RIA
Unparallel Innovation, Lda	UNP
Gottfried Wilhelm Leibniz Universität Hannover	LUH

*LHF 4.0 – Lighthouse Factory 4.0 * RF – Replication Factory 4.0

Executive Summary

The present document is the first report of the activities developed in tasks T2.1 and T2.2. These tasks address the definition of the Pilot's requirements and technical specifications for each of the pilots in the Boost 4.0 project.

This deliverable covers the introduction to each of the lighthouse factories, describing the general concept of the pilot, the main objectives and the participants (the main partner and the technical partners).

Each pilot has up to two scenarios with several processes that will be transformed through the Boost 4.0 initiative, so all the business requirements are explained for each of these processes, and finally the technical specification for each of the factories, starting from the legacy systems to the system requirements and ending with the design decisions to be made.

Summarizing, the 10 trials involved in the project are:

In trial 1, Volkswagen, ESI Group and ATB intend to develop a new approach to gather data from the injection moulding process to understand, diagnose, predict and finally to prescribe the conditions in the manufacturing process for an optimal overall equipment effectiveness.

In trial 2, FILL, TTTech, Visual Components and RISC Software will work to improve the engineering processes by gathering, transmitting and analysing data from the products to the engineers to detect design faults and unattended requirements and to develop data-based 3D simulations.

In trial 3, VW Autoeropa together with Uninova, Visual Components, ASTI and Telefónica wants to fulfil the automation of the automate the entire handling process, from the warehouse to the assembly line, including the process of sequencing and transporting the rack to the point of fit in the assembly line.

In trial 4, +GF+, EPFL and ESI Group will demonstrate the benefits of a fully digitalized and real-time controlled system by monitoring the machines that manufacture spindles and the parts they produce as well as the assembly line targeting the maximum productivity and quality

In trial 5, FIAT, Prima Industries and Siemens intend to use available and new datasets (such as flows of components in the plants and their precise localization) to provide maximum flexibility to potential changes in demand or to issues/delays/changes in the logistics or productive systems.

In trial 6, Phillips will join forces with Philips Research and IMEC to integrate data from different sources and analyze it to give advanced notice of anomalous behavior and/or tool malfunction and also to understand better the moulding process.

In trail 7, Gestamp, Innovalia, I2Cat, Eneo, Trimek and Capvidia will integrate inline inspection solutions for quality control in order to analyse and manage quality information about great number of components as well as finished and complex products.

In trial 8, Volvo, Certh/ITI and Chalmers will work to track the transportation of components between two plants, gathering information from different sources to improve the planning process, prevent delays and better react to unavoidable problems.

In trial 9, Whirlpool, together with SAS and Politecnico di Milano, will develop a prediction tool based on historical demand of the spare parts and other endogenous variables to optimise the spare parts planning and distribution process.

Finally, in trial 10, Benteler, Fraunhofer FEM and Atlantis Engineering will establish and roll out a predictive maintenance framework based on a standardized process leading to a vision of an intuitive, integrated tool for monitoring of machine condition and planning of actions.

Keywords: Pilot overview, pilot participants, business requirements, technical specifications, legacy systems,

Disclaimer

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Abbreviations and Acronyms

Acronym	Meaning
A.I.	Artificial Intelligence
ANN	Artificial Neural Network
API	Application Programming Interface
BIW	Body In White
CEP	Complex Event Processing
DSS	Decision Support System
ERP	Enterprise Resource Planning
FDT	Fault Detection Tool
IoT	Internet of Things
KPIs	Key Performance Indicators
ML	Machine Learning
MES	Manufacturing Execution System
OS	Operating System
PaaS	Platform as a Service
PMT	Predictive Maintenance Tool
RDBMS	Relational Database Management Systems
SIEM	Security Information and Event Management
SPC	Spare Part Centres
SSA	Singular Spectrum Analysis
SMS	Smart Manufacturing Systems

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1 Introduction

This is the first deliverable to report the progress of Task 2.1, with the objective of explaining the main requirement of each of the pilots.

As the implementation process will be an iterative and incremental process, there will be a second deliverable for this task to report the evolution of the requirements and the pilots.

1.1 Scope and organisation

This document, together with deliverable D2.3, lay the foundations for the development of the experiments in WP 4-8, as they explain what each of these pilots consist of.

This deliverable, is organised as follows: there is a chapter for each of the pilots, and within each chapter there are three sections: a general overview (whit a small description of the pilot, the main objectives and the participants in the pilot) and then the business requirements and the pilot specification, where it will be described in each case what has to be considered in the definition of each of the pilots.

1.2 Methodology

As this is the first deliverable of workpackage 2, it is the perfect document to introduce the methodology used to gather the important information in the project in order to fulfil the reporting of the project in the most efficient way. This methodology is based on the analysis and adaptation of Requirements Engineering techniques and methodologies carried out in FITMAN[1].

Each pilot in the project will have a Handbook to collect the information source for all tasks dealing with the BOOST 4.0 trial implementation.

Each Trial will write and be responsible of its own deliverables and of the gathered information, however in order to better coordinate and align the development of activities inside the ten trials, **the handbook will provide a common structure to gather and present data**. This approach will also:

- Facilitate the work within the different trial factories
- Prevent overlapping among tasks
- Avoid duplication of efforts
- Ensure the schedule accomplishment

[1] FITMAN is a FI-PPP Phase II project, developing and applying Future Internet (FI) technologies to manufacturing industries.

From previous analysis of the different methodologies, it is clear that an iterative approach is the most suitable method when dealing with the definition of requirements, no matter the type of project we are attempting.

Most of the methodologies propose a sequence for the whole process of requirements definition, including in most cases different steps that can be summarized in: understanding of customers' context, elicitation, analysis, negotiation, and evaluation/definition. In the proposed FITMAN approach also a trusted method for data acquisition has been defined that was created on the basis of the methodology of **Wellington**[2] created in "Research Methods for the Social Sciences". The Wellington methodology follows a 4-step method:

1. Brainstorming
2. Classifying and categorising
3. Creation of the guide
4. Interview schedule

The FITMAN revision of Wellington consists on the adaptation of the steps to the real requirements centred on our Ecosystem's use case. Thus, the steps to be followed are:

1. Conceptual design. Approach discussion and agreement
2. Classifying and categorising the content
3. Creation of the template/interview
4. Template and Interview schedule

The specific procedure to gather the information will therefore follow the next steps:

1. **Conceptual design. Approach discussion and agreement**: In this stage, we developed an initial idea to attempt the data gathering and define a first version of the questionnaires that was discussed with the rest of the work packages 1 and 2 participants. After an initial agreement, we planned a schedule for a review and second release of the questionnaires.
2. **Classifying and categorizing the content**: In this phase, we discussed, analysed and reviewed the content we need to include in the questionnaires and the format of the different paragraphs to achieve a certain degree of harmonization and quality.
3. **Creation of the template/interview**: After the classification and categorization of the content that the questionnaires had to contain, we develop a final version of the questionnaire that was delivered to the Trials. We also planned the preliminary

[2] Wellington, Jerry, and Marcin Szczerbinski. Research Methods for the Social Sciences. London: Continuum International Publishing, 2007

content of the interviews in order to assure accomplishment of schedule and effectiveness.

4. **Template and Interview schedule**: We finally entered in an iterative phase where interaction with the trials was done to assure understanding, length, coherency and quality of the information delivered. This phase holds the delivery and feedback of questionnaires and the interviews for final adjustments, corrections and fulfilment of required information.

The questionnaire has been completed after several meeting among the stakeholders involved in the process, where a careful analysis of the relevant information to be collected has been carried out. These meetings and interviews had the purpose to clarify the contributions made and to fine-tune further refinements in the elicitation process. The collected information is incorporated into a master document.

The workflow implemented for the generation of the present document is presented in Figure 1-1.

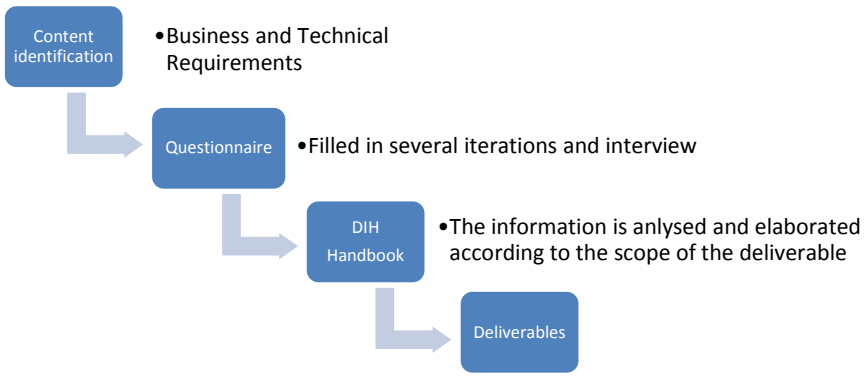

Figure 1-1 - BOOST Information gathering workflow

2 Trial 1: Volkswagen Injection Moulding Plant

The section consists of two main parts and provides details for trial 1:

1. **Pilot overview**
   Provides explanations about the manufacturing processes and plants involved in the trial. Additionally, it explains the objectives to be achieved and the partners involved.
2. **Business requirements**
   This section provides an overview of the business processes involved in the trial.
3. **Pilot specification**
   Details the technical specifications required in order to realize the solution for each trial. This includes descriptions of legacy systems to be integrated, software components, and software requirements.

2.1 Pilot overview

2.1.1 General description

The Volkswagen Group, with its headquarters in Wolfsburg, is one of the world's leading automobile manufacturers and the largest global carmaker in terms of sold vehicles (ca. 10.7 Mio cars produced per year).

Figure 2-1: Filling aluminium into a sand mould

Project partner will be the Volkswagen component tool shop in Braunschweig, internal provider of tools for light metal casting (see Figure 2-1), injection moulding and forming processes for many other factories each with a large number of machines. Continuous increasing requirements towards product design and quality requirements and therewith narrowing process windows demand feedback to design & manufacturing of tools as well

as prevention of tool and/or machine related issues by prediction are key for effective operation of complex processes such as light metal casting, injection moulding, additive manufacturing or complex sheet metal related work.

The component tool shop represents the key department in a circular relationship between the design of cars and the production related steps (i. e. pre-series production & test, regular production, maintenance, infrastructure management). The component tool shop as kernel department is already operating some 40 milling machines, 20 turning & sanding machines and 5 eroding machines that are used to manufacture diverse tools for additional types of manufacturing processes (i. e. tools for metal casting, injection moulding, assembly and metal press). Those different manufacturing processes are imposing different challenges on how to use data, for generating information and knowledge.

Especially metal casting is a manufacturing process that is operated at high temperatures (i. e. in ranges from 660-1500 °C) where process parameters cannot be easily monitored by usual sensors and measurement approaches. At the same time, there is rather limited knowledge available on the usage of measured process parameters for monitoring and adjusting the process directly. On top of that, diverse sources of untapped data needs to be processed and analysed for being able to find potential implications of design decisions with respect to the automotive part (see Figure 2-3 and Figure 2-4), used alloy, mould (see Figure 2-2) and machine. However, the current manufacturing process is somehow a black box handled rather based on past designs and engineers' profound technical competency. The metal casting process itself does not use detailed deterministic real-time process control models. The motivation is to develop related models based on an evolutionary learning from data collected in different life cycle phases of the manufacturing process. Therefore, the use case shall correlate the data that can be collected in the different product and process life cycle phases (e. g. mould design, machine set-up, tool & machine operation, maintenance as well as quality monitoring w.r.t. the automotive part).

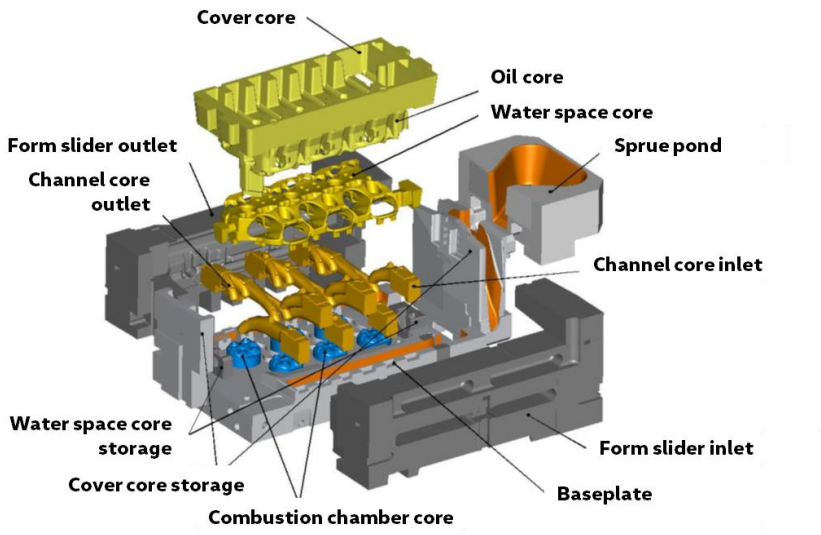

Figure 2-2: A light metal casting mould

Therefore, in Boost 4.0 VW aims at developing new Industry 4.0 related approaches and systems for gathering large amounts of data for being able to understand, diagnose, predict and finally to prescribe the conditions in the manufacturing process for an optimal overall equipment effectiveness. This requires an integrated approach for modelling information, gathering data, deriving information & knowledge as well as to transfer the approach to diverse departments locally and at diverse locations and possibly even transferring related knowledge to first tier suppliers. Finally, for being able to generate knowledge that will facilitate the achievement of a zero-defect objective it is envisaged to develop a modular improvement approach that allows for an evolutionary introduction in heterogeneous manufacturing environments. It shall be possible to use the approach in departments that are operating old machines and tools with rather limited abilities for data provision as well as with machines, moulds and tools that are already able to provide rich data sets in real time.

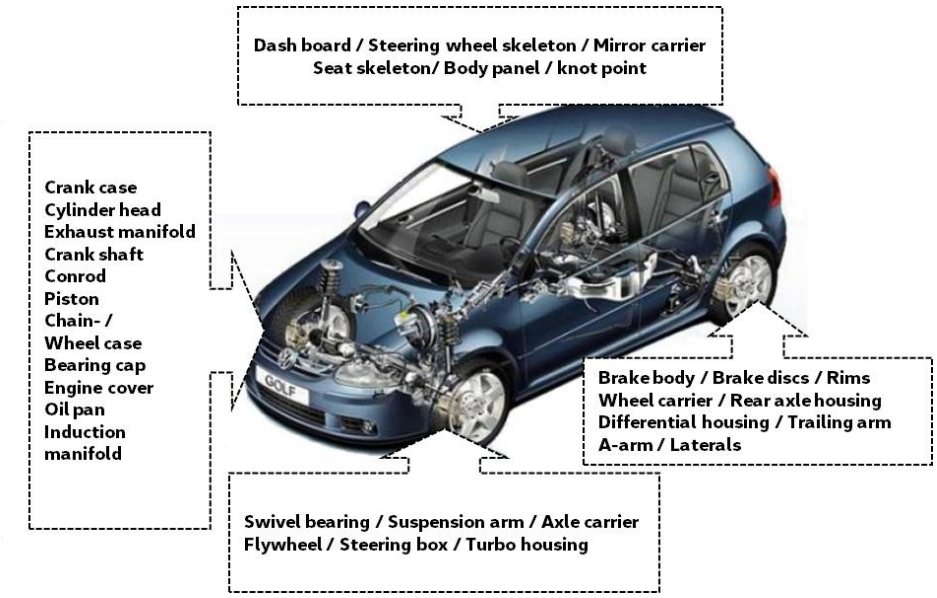

Figure 2-3: Light metal casting parts in a vehicle

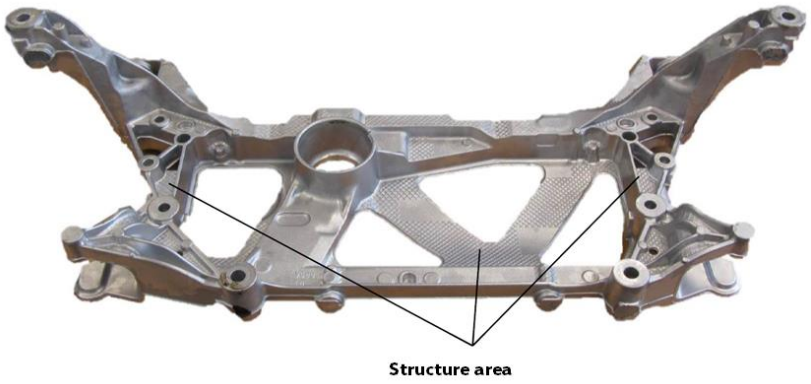

Figure 2-4: A produced part in the light metal casting process

Nevertheless, the current key obstacle is the missing possibility to measure data directly in the metal casting mould, due to the lack of sensors that can be operated within the mould at the process temperatures.

Table 2-1 Trial 1 application domains

Application Domain*		Description and justification of the application domain
SMART FACTORY	X	The metal casting machines are currently not able to receive process data from the moulds, due to the process conditions and availability of sensors that can handle related requirements. Novel control models could improve the process control and reduce the number of defective parts.

Application Domain*		Description and justification of the application domain
DIGITAL FACTORY	X	The manufacturing process of metal casting is characterised by the development of moulds that shall have a long-life time (i. e. depending on the used type of metal/alloy, from 100,000 to up to 2 Mio parts produced). At the same time, it is difficult and currently for certain data rather impossible to provide proper measurements. Digital devices and their integration are required for being able to exploit related data within specific engineering platforms and services. There are additional initiatives and projects running at VW that are gathering data and making it available to enable the answering of specific questions. However, due to the pure seize of VW and the distributed setting of production/assembly facilities, there is no one size fits all digital infrastructure that enables interoperability between different life cycle phases or even opening up communication channels towards the product (i. e. car) when it is in operation at VW customers.
VIRTUAL FACTORY	X	VW is operating the value adding process via different shop-floors, sites, and even countries. At the same time, there is also an intense collaboration with suppliers of machines, tools and parts. It shall be validated on how to consider this distributed setting as a seamless space for cooperation towards the production of specific car models.

2.1.2 Objectives

The Volkswagen pilot will implement a set of interconnected processes that will **boost effectiveness of production, reduce costs and increase quality in light metal** casting and resulting parts. The strategic objective is to realise the following:

- *Real-time continuous tool condition monitoring.* Automated experience and simulation-based approach using sensor data and big data analysis methods potentially transferable to other production processes.
- *Simulated tool-health prediction models:* The mould health state needs to be predicted for process parameter adjustment or immediate tool maintenance

- *Integrated mould design:* Big data from mould usage and data from external plants and suppliers needs to be combined and analysed with production data (e. g. product geometry, mould temperatures, acoustic sensors, thermal and optical sensors and imaging) and mould sensor data for better mould commissioning.
- *Smart product data.* Engineering modules that will integrate and analyse "smart vehicle big data" as the feedback loop to improve automotive part quality, mould design processes and production cost-efficiency.

Based on those results, VW aims at the realisation of a kind of assistance systems for manufacturing processes to achieve the following:

- fine granular and differentiated tracking of manufacturing processes
- increasing process and product transparency
- understanding multi variate dependencies and anomalies.

All this shall help to reduce the defective parts produced in the scope of light metal casting and hence to reduce waste and increase productivity. At the same time, the engineering shall be supported with knowledge that is currently not yet available, for being able improve the mould design and reduce engineering efforts. Therefore, it is envisaged to improve the product quality (i. e. mould and automotive part), reduce costs as well as to reduce time for engineering

2.1.3 Participants

You can find an extended description for each of the participant in APPENDIX 1: Participant description

Table 2-2 Trial 1 participants

Volkswagen	Largest carmaker in Europe. 12 brands in 7 countries 121 production plants in 20 countries in Europe, and 11 worldwide	Main partner Will host the trial at the component tool shop in Braunschweig
esi get it right®	Leading innovator in virtual prototyping software and services	Will provide with the ICT solution for the big data analytics and simulation in the pilot
ATB	Insitut für Angewandte Systematechnik Bremen GMBH Research Institute	Lead pilot analysis and set-up Implementation of the Assistant System Support on the definition and measurement of KPI's

2.2 Business requirements

This section specifies the business requirements that the solution that will be implemented in the VW pilot must meet:

- The solution assures security of data collected – no data leaks and access by unauthorised actors
- The solution is in compliance with the VW standards
- It has to be easy to add new sources of data (sensors, machines, car data, garages etc.)
- The solution provides an easy to use interface to the operator:
    - Provides specific data
    - Allowing to compare "similar" processes/products
    - Allowing to detect patterns that may lead to errors
    - Warning when errors occur or are foreseeable
    - Giving contextual information
    - Allowing certain personalization (what alarms are active etc.)
- The solution must reduce reaction time to errors by reducing the timing of analysis
- The solution provides a unified data access and infrastructure
- The outcomes should be aligned and synchronized with other related projects

2.3 Pilot specification

This section details the technical specifications required in order to realize the solution for trial 1. The section is organized in three sub-sections:

1. **Legacy systems**

   This sub-section provides an overview of existing data sources in the factory such as databases, sensors, etc. These sources will provide the data for the solution that address the trial's business requirements.

2. **Components and infrastructure**

   This sub-section provides an overview of the components that make up the solution for trial 1.

3. **System requirements**

   This sub-section provides an overview of the features required to address the business requirements of trial 1.

4. **Design decisions**

This sub-section details design decisions that affect the development of the solution for trial 1.

2.3.1 Legacy Systems

The paragraph consists of a series of tables detailing the legacy systems involved in the solution for trial 1. The description includes relevant APIs, data formats, etc. along with details relevant to big data such as data volume, velocity etc.

Table 2-3 Volkswagen ICT Infrastructure

Legacy system name		Volkswagen ICT Infrastructure
Type		Data Source Environment
Details	*APIs*	SQL data access, OPC-UA SDK
	Data Format	OPC-UA access, CAD, XML, JSON

Big Data Characteristics (if applicable)	*Volume (size)*	~ 20 GB persistent data per part and mould ~ 2 GB per process per day **Per simulation** (9 simulations for initialization, new simulations computation during the number of years producing a part): - ~25GB compressed binary file (HDF5) **Multiplier**: *Pre-Process-Data:* Number of Projects / year (> 10x) Number of design changes (rare) Number of internal VW-casting plants (4x) Number of external VW-casting parts supplier (>10x) *Process Data*: Number of sensors within in mould & each machine (>20x) Number of moulds & machines in one production line (~ 10x) Number of production lines (up to 10x) Number of production days / year (>300x) Number of years producing a part (~ 5x) *Quality Check Data:* Number of produced parts (> 2 Mio. / plant) Rate of each Quality Check (between 10% & 100% of the total amount of parts) *Usage Data:* Number of cars / year Rate of services / car
	Velocity (e. g. real time)	From real-time data (e. g. process measurements) Live Data (e. g. vehicle data) Persistent data (e. g. design data)
	Variety (multiple datasets, mashup)	High variety of data addressing several data sources which provide individual data volume, structure and velocity.
	Variability (rate of change)	Low variability through fixed data formats.

Other Big Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*	High Veracity through technical data and selected precise data sources.
	Visualization	Volkswagen uses already simulation software which provides also information in form of visualisations.
	Data Analytics	

2.3.2 Components and infrastructure

The paragraph consists of a series of tables detailing the components in the solution for trial 1. The description covers functionalities, data input/output, data formats, and integration needs of the components.

2.3.2.1 ESI Cloud platform for casting simulation

Table 2-4 ESI Cloud platform for casting simulation

ID			BC-ESI-1
Responsible partner			ESI
Tool name			ESI Cloud platform
Overall Description			Virtual prototyping and data analytics for casting simulation
Details	*Functionalities offered*		1. Workflow for casting simulation & analysis coupled with real casting sensor feedback. 2. Casting simulation & analysis leads to create a comprehensive map (DNA like) of behaviours identified during simulations 3. Sensor feedback leads to alert any deviation (coming from bad simulation calibration or problem occurring during real casting process) from the simulated cartography identified in 1.
	Data input	*Description*	- Preprocessed simulation model (ready for simulation) • Casting process parameter
		Format	Simulation model built in a preprocessing step with the Visual Mesh/Cast tools.
	Data Output	*Description*	- Casting simulation results - Cartography of simulations Alerting
		Format	ERF-format (HDF5 based), csv, etc.
	Integration requirements		
	BDVA mapping		

2.3.2.2 INENDI Inspector

Table 2-5 INENDI Inspector

ID			BC-ESI-2
Responsible partner			ESI
Tool name			INENDI Inspector
Overall Description			The INENDI Inspector solution is a software solution that allows any user to handle large amounts of structured or semi-structured data and perform a very rich and deep investigation of the data. Thanks to a set of intuitive and very interactive visualizations of this dataset, the user experience is freed from the classical burden of query-based interactions and the latter can use all his/her logical and deductive power to learn valuable insights from the data. It can be used for different purposes: Initial understanding of large and complex data sets. Discover and describe the detailed structure of datasets. Isolate weak signals very efficiently. Control and improvements of ML algorithms
Details	*Functionalities offered*		1. Data analysis with basic statistical tools 2. User interface 3. Interactive visualization 4. Multiple databases with interaction between these databases
	Data input	*Description*	• Sensor data from robots • Production / Quality / Sales / Financial data • Alpha numeric data sets • Binary files coming from Packet capture or softwares like Splunk, Elasticsearch, mysql/postgres db • Ascii files • Compressed text files • Set of files
		Format	Text files, compressed text files (gz/bz2/zip), pcap, binary (splunk, elasticsearch, mysql)
	Data Output	*Description*	Subsets of data
		Format	Text files, compressed text files (gz/bz2/zip), pvi (binary proprietary format)
	Integration requirements		Any Linux distribution supporting Flatpak
	BDVA mapping		

2.3.3 System requirements

The paragraph consists of a series of tables detailing the software requirements in terms of features addressing the business needs of trial 1. The details include, associated

business requirements, an overview of the functionality, data input/output, relevant software requirements of the feature, interfaces, performance and other non-functional requirements.

2.3.3.1 Data Marketplace

Table 2-6 Data marketplace

ID	VW-DM-1
Business requirement reference	• BOOST 4.0 provides solution to access to data from vehicles (agreement with users/vehicle owners) • BOOST 4.0 provides an approach for QoS-adaptive data processing and data aggregation inside the vehicle • BOOST 4.0 provides an approach to increase the amount & number of different data coming from vehicles used as a feedback to design. • BOOST 4.0 provides approaches to assist mould designers in the creation of moulds with a higher durability. • BOOST 4.0 provides possibilities to use vehicle data for a feedback to mould design. • The data aggregation within the vehicle shall be cost effective. • The feedback from garages on problems with light metal parts during the vehicle use is correlated with data streams from vehicles. • The solution provides architecture allowing to use data streams from geographically distributed vehicles • The solution provides support for effective selection of data from vehicles which can be used for mould design • The synergies between other projects in the Volkswagen Pilot shall be establish to re-use solutions for data market
Overall Description	The Data selection method uses meta-data and context data of systems in the Volkswagen light metal casting process to provide data (stream) management functionalities including search, filter, selection and preparation of data (streams) for a subsequent Big Data analysis. Available systems have to be registered as data producers and have to provide their meta data which describe life-cycle information, providable data (streams), and connections to their physical and virtual environment (e. g. physical connections to other CPS, connection points to the electrical infrastructure; or virtual dependencies on services). Additional context information can be optionally provided (event-based or frequently updated). Based on these meta-data Searching, Filtering and Selection (SFS) features are provided. After the selection of needed data, a sub-catalogue of selected data, enriched with access information to the data sources is provided. This sub-catalogue can be loaded by a CPS Data Preparation module which provides the selected data for a sub-sequent big data analysis

Feature	*Introduction & Purpose of feature*	Exploitation of meta-data provided by data ecosystem participant for and easy identification and selection of needed data for a sub-sequent data analysis.
	Stimulus Response Sequence	
	Functional Requirements	Data Searching, Filtering and Selection (SFS) features as e. g. •SFS of single CPS •SFS of life-cycle data •SFS of CPS or data (streams) of a specific category •SFS of data buckets or streams •Context dependent SFS Data preparation and provision functionalities of selected data for a sub-sequent big data analysis.
External Interface Requirements	*User Interfaces*	Functionalities for SFS for data sources based on provided meta-data
	Hardware Interfaces	It is assumed that connected hardware shall participate via connectors in the data ecosystem. No hardware interfaces are required.
	Software Interfaces	* Legacy systems able to provide meta-data, context data and produced raw data. * Big Data Solution which uses selected prepared raw data for data analytics purposes.
	Communications Interfaces	
Performance Requirements		SFS features should be well usable by humans (response <1 second)
Other non-functional requirements		-

2.3.3.2 *Manufacturing Process Warning*

Table 2-7 Manufacturing Process Warning

ID	VW–MPW-1
Business requirement reference	- The solution warns (pro-actively) the operator and shop floor manager on (potential) problems in manufacturing process - The solution allows user to select to which problem occurrence (s)he will be warned - The solution combines data from various sources to compute warnings to be issued to design - The solution issues the warning in the form which is suitable for the operator (user) – t. b. d.
Overall Description	***SW Module: Warning on problems in the manufacturing processes*** The software warns (pro-actively) the operator and shop floor manager on (potential) problems in manufacturing process. The software module gets from the Data Analytics Module the patterns identified in the data streams from the manufacturing processes (machines, moulds) and if the pattern indicates potential problems in the

		manufacturing processes, the user (operator, shop-floor manager) is warned over GUI. The objective is to allow for prompt reaction to problems based on continuous tool condition monitoring. Through more available information/data from moulds and machines, a more prompt reaction is possible based on observed parameter which are currently hidden. A prompt reaction in case of unintended behaviour could decrease the rejection rate of light metal casting parts and can avoid bigger failures.
Feature	*Introduction & Purpose of feature*	***Manufacturing Process Warning Feature***: The feature warns (pro-actively) the operator and shop floor manager on (potential) problems in manufacturing process
	Stimulus Response Sequence	Input & output description Input: Recognised data patterns in data flowing from manufacturing processes Output: Warning(s) to the user(s) over GUI Stimulus: The pattern in data flow from the manufacturing processes (machines, moulds) is identified by the Data Analytics module. Two options (t.b.d.): a) The Data Analytics module sends all identified patterns at the given sampling interval, e. g. every 5 minutes and then the Manufacturing Process Warning Feature "decides" whether or not the pattern indicates the potential problems in the manufacturing processes b) The Data Analytics module pre-filters the identified patterns and sends only those which may indicate the problems in the manufacturing processes Response: If the identified patterns indicate the potential problems in the manufacturing process, the warning is issued to the user(s) over GUI Sequence: - Identified data patterns coming from the Data Analytics module (see options above) - The validity of the inputs (recognised patterns) is checked based on the defined rules– see above two options for Stimulus - Check if the identified patterns match with the warning conditions selected by the user - Issue warning(s) to the user(s) over GUI - Allow the user to request and get additional information related to the warning

	Functional Requirements	The solution shall: - Check validity of the inputs (recognised patterns) based on the defined rules– see above two options for Stimulus - Check if the identified patterns match with the warning conditions selected by the user - Issue warning(s) to the user(s) - Allow the user to request and get additional information related to the warning The solution shall in set-up mode: - Offer possible warnings to the user - Allow the user to select which warning conditions should be activated and sent to her/him - Administrator set-up: may define/change rules to identify if the patterns indicate possible problems in the manufacturing process or not – see above options for Stimulus
External Interface Requirements	*User Interfaces*	- The solution issues the warning in the form which is suitable for the operator (user) – t. b. d. - Warning to the operator can be presented to other users, e. g. shop floor manager and for each user the presentation of the warnings at GUI are adjusted to her/his needs In set-up mode: GUI will present the list of possible Warnings and the user may select which Warnings are relevant for her/him. The GUI must all overview of all warnings – so minimal information (but include information to understand what the warning real means) Administrator set up: GUI presents set of defined rules in the form IF … THEN … to identify if the pattern(s) may indicate potential problems in the production line and allows the administrator to select the rules to be applied and or add new rule
	Hardware Interfaces	This module/feature shall not have direct interface with HW components, the data sources
	Software Interfaces	Directly interfaced to Data Analytics Module – see above
	Communications Interfaces	Specify the various interfaces needed for communication with other software/hardware components
Performance Requirements		- The warning includes all data the user (operator) needs to identify the problem and decide on further actions - The time between the occurrence of the indication of potential problems in the manufacturing process and the warning issued at operator shall not be longer than t. b. d.
Other non-functional requirements		- The solution is in compliance with the VW standards - The solution assures security of data collected – no data leaks and access by unauthorised actors

2.3.3.3 Design Warning

Table 2-8 Design Warning

ID	VW-DW-1	
Business requirement reference	- The solution warns (pro-actively) the designer on (potential) problems in manufacturing process and vehicles in use - The solution allows user to select to which problem occurrence (s)he will be warned - The solution combines data from various sources to compute warnings to be issued to design - The solution issues the warning in the form which is suitable for the designer (user) – t. b. d. -	
Overall Description	*SW Module: Warning on problems in the manufacturing processes* The software warns (pro-actively) the designer on (potential) problems in manufacturing process and vehicles. The software module gets from the Data Analytics Module the patterns identified in the data streams from the manufacturing processes (machines, moulds), and/or from vehicles (including information from garages) and if the pattern indicates potential problems in the manufacturing processes and the vehicles, the user (designer) is warned over GUI. The objective is to allow for prompt reaction to problems based on continuous tool condition monitoring and feedback from vehicles in use. Through more available information/data from moulds and machines, a more prompt reaction is possible based on observed parameter which are currently hidden.	
Feature	*Introduction & Purpose of feature*	*Manufacturing Process Warning Feature*: The feature warns (pro-actively) the designer on (potential) problems in manufacturing process and vehicles in use.
	Stimulus Response Sequence	Input & output description Input: Recognised data patterns in data flowing from manufacturing processes and vehicles in use (from the Data Analytics module- INENDI Inspector) Information from garages on problems with light metal parts Output: Warning(s) to the user(s) over GUI Stimulus: The pattern in data flow from the manufacturing processes (machines, moulds) and/or warning from garages and pattern in data from vehicles in use is identified by the Data Analytics module. Two options (t.b.d.): c) The Data Analytics module sends all identified patterns at the given sampling interval, e. g. every 5 minutes and then the Design Warning Feature "decides" whether or not the pattern indicates the potential problems d) The Data Analytics module pre-filters the identified patterns and sends only those which may indicate the problems in the

		manufacturing processes and/or vehicles in use Response: If the identified patterns indicate the potential problems in the manufacturing process and/or vehicles in use, the warning is issued to the user(s) over GUI Sequence: - Identified data patterns coming from the Data Analytics module (see options above) and Information from Garages - The validity of the inputs (recognised patterns) is checked based on the defined rules– see above two options for Stimulus - Check if the identified patterns match with the warning conditions selected by the user - Issue warning(s) to the user(s) over GUI - Allow the user to request and get additional information related to the warning
	Functional Requirements	The solution shall: - Check validity of the inputs (recognised patterns) based on the defined rules– see above two options for Stimulus - Check if the identified patterns match with the warning conditions selected by the user - Issue warning(s) to the user(s) - Allow the user to request and get additional information related to the warning The solution shall in set-up mode: - Offer possible warnings to the user - Allow the user to select which warning conditions should be activated and sent to her/him - Administrator set-up: may define/change rules to identify if the patterns indicate possible problems in the manufacturing process or in vehicles in use or not – see above options for Stimulus
External Interface Requirements	*User Interfaces*	- The solution issues the warning in the form which is suitable for the designer (user) – t. b. d. - Warning to the designer can be presented to other users, e. g. shop floor manager and for each user the presentation of the warnings at GUI are adjusted to her/his needs In set-up mode: GUI will present the list of possible Warnings and the user may select which Warnings are relevant for her/him. The GUI must all overview of all warnings – so minimal information (but include information to understand what the warning real means) Administrator set up: GUI presents set of defined rules in the form IF … THEN … to identify if the pattern(s) may indicate potential problems in the production line and/or vehicles and allows the administrator to select the rules to be applied and or add new rule

	Hardware Interfaces	This module/feature shall not have direct interface with HW components, the data sources
	Software Interfaces	Directly interfaced to Data Analytics Module – see above Direct Information flow from garages
	Communications Interfaces	Specify the various interfaces needed for communication with other software/hardware components
Performance Requirements		- The warning includes all data the user (designer) needs to identify the problem and decide on further actions - The time between the occurrence of the indication of potential problems in the manufacturing process and the warning issued at designer shall not be longer than t. b. d. - The time between the occurrence of the problem in vehicle use and the warning issued at design shall not be longer than t. b. d.
Other non-functional requirements		- The solution is in compliance with the VW standards - The solution assures security of data collected – no data leaks and access by unauthorised actors

2.3.3.4 VW Connector to EIDS

Table 2-9 VW Connector to EIDS

ID	VW-C-1	
Business requirement reference	The solution provides architecture allowing to use data streams from geographically distributed manufacturing processes in VW The solution provides architecture allowing to use data streams from moulds from geographically distributed manufacturing processes in VW The solution allows to integrate data from external stakeholders, i. e. suppliers	
Overall Description	The connector provides connection, interface, between VW internal Data Infrastructure external Data Infrastructure. The connector will connect the VW Data Infrastructure with EIDS architecture which allows for integration of data flowing from various geographically distributed VW subsidiaries, suppliers and other stakeholders. The connection will map (transform) data streams from VW data model to EIDS compliant data model and vice versa	
Feature	*Introduction & Purpose of feature*	The purpose is to allow for effective integration of data streams from geographically distributed sources within VW network. The integration can be done over an EIDS (compliant architecture) and, therefore, the connector between the VW Data Infrastructure and such architecture is needed
	Stimulus Response Sequence	Inputs - Data streams from VW Data Infrastructure - Data streams from EIDS (geographically distributed sources) Outputs:

		- Data streams to VW Data Infrastructure - Data streams to the EIDS architecture Stimulus: Data streaming either from VW Data Infrastructure of from EIDS
	Functional Requirements	The component shall include validity checks on the data inputs The component shall support mapping (transformation) between VW data model and EIDS data model The component shall provide diagnostic when problems in data streaming occur
External Interface Requirements	*User Interfaces*	No direct interface with the user
	Hardware Interfaces	Interface to VW data infrastructure Interface to EIDS architecture
	Software Interfaces	Security components
	Communications Interfaces	
Performance Requirements		1. Amount and type of information to be handled 2. Response duration in time
Other non-functional requirements		- The solution is in compliance with the VW standards - The solution assures security of data collected – no data leaks and access by unauthorised actors

2.3.3.5 Data selection method

Table 2-10 Data selection method

ID	VW-DSM-1
Business requirement reference	* The data streams from machines are semantically enriched based on the adopted semantic data models. * BOOST 4.0 provides an approach (ICT infrastructure) to integrate (legacy) machines into a unified data infrastructure. * BOOST 4.0 provides an approach to collect data from machines and moulds through an (open) platform solution. * BOOST 4.0 provides an approach to read data from machines and moulds through an open platform solution. * BOOST 4.0 provides semantical data models and unified data access to data streaming from vehicles in use. * The data streams from machines are semantically enriched based on the adopted semantic data models.

Overall Description		The Data selection method uses meta-data and context data of systems in the Volkswagen light metal casting process to provide data (stream) management functionalities including search, filter, selection and preparation of data (streams) for a subsequent Big Data analysis. Available systems have to be registered as data producers and have to provide their meta data which describe life-cycle information, providable data (streams), and connections to their physical and virtual environment (e. g. physical connections to other CPS, connection points to the electrical infrastructure; or virtual dependencies on services). Additional context information can be optionally provided (event-based or frequently updated). Based on these meta-data Searching, Filtering and Selection (SFS) features are provided. After the selection of needed data, a sub-catalogue of selected data, enriched with access information to the data sources is provided. This sub-catalogue can be loaded by a CPS Data Preparation module which provides the selected data for a sub-sequent big data analysis.
Feature	*Introduction & Purpose of feature*	Exploitation of meta-data provided by data ecosystem participant for and easy identification and selection of needed data for a sub-sequent data analysis.
	Stimulus Response Sequence	Data stream management functionalities including search, filter, selection and preparation of data.
	Functional Requirements	Data Searching, Filtering and Selection (SFS) features as e. g. •SFS of single CPS •SFS of life-cycle data •SFS of CPS or data (streams) of a specific category •SFS of data buckets or streams •Context dependent SFS Data preparation and provision functionalities of selected data for a sub-sequent big data analysis.
External Interface Requirements	*User Interfaces*	Functionalities for SFS for data sources based on provided meta-data.
	Hardware Interfaces	It is assumed that connected hardware shall participate via connectors in the data ecosystem. No hardware interfaces are required.
	Software Interfaces	* Legacy systems able to provide meta-data, context data and produced raw data. * Big Data Solution which uses selected prepared raw data for data analytics purposes.
	Communications Interfaces	-
Performance Requirements		SFS features should be well usable by humans (response <1 second).
Other non-functional requirements		---

2.3.3.6 Maintenance Assistant Module

Table 2-11 Maintenance Assistant Module

ID	VW-MAM-1	
Business requirement reference	- Assistant systems provide information useful for failure avoidance - Assistant systems provide information useful for predictive maintenance - BOOST 4.0 provides an approach to provide processed data as real-time monitoring assistant system in production. - BOOST 4.0 provides approaches to assist machine operators in increasing the process transparency. - BOOST 4.0 provides approaches to assist machine operators to gain knowledge about what is happening in the light metal casting process (including e. g. history over time period) - BOOST 4.0 provides approaches to reduce the rejection rate through data analytics in the light metal casting process. - BOOST 4.0 provides assistant systems in production which transform data analytics results into information usable by the operator - BOOST 4.0 provides approaches to react in advance on upcoming failures to avoid process disturbances. - BOOST 4.0 provides approaches to reduce the maintenance time needed for a mould in the light metal casting process.	
Overall Description	*SW Module: Maintenance Assistant Module* The software provides the operator and shop floor manager with data on current status of the production processes and predict (potential) problems in manufacturing process. The software module gets from the Data Analytics Module the patterns identified in the data streams from the manufacturing processes (machines, moulds) and the patterns are presented in the appropriate forms to the users (operators, shop-floor-management) aiming to provide information on the status manufacturing processes. The objective is to allow for reaction to potential predicted problems based on continuous tool condition monitoring. Through more available information/data from moulds and machines, a more appropriate reaction (maintenance) is possible based on observed parameter which are currently hidden.	
Feature	*Introduction & Purpose of feature*	*Maintenance Assistant Module:* The feature assists the operator and shop floor manager to get a comprehensive overview of the status of the manufacturing problems and react on (potential) problems in manufacturing process.
	Stimulus Response Sequence	Input & output description Input: Recognised data patterns in data flowing from manufacturing processes (from the Data Analytics module)

		Prediction of the process and tools status (ESI Cloud platform) Output: Data on current status of the manufacturing processes over GUI Stimulus: The behaviour of the pattern in data flow from the manufacturing processes (machines, moulds) is identified by the Data Analytics module. The possible problems are predicted by the simulation Two options: - Analytic Modules (ESI Cloud platform) continuously sends the information on patterns and predictions - The user requires patterns and/or predictions – to get info on the current status of the production lines Response: The Maintenance Assistant transforms the information on patterns in information needed (suitable) by the operators and shop floor managers and presents them over GUI (which may include graphics etc.) Sequence: - Identified data patterns coming from the Data Analytics module (see options above) - Data patterns may be used to predict state of the processes and tools (ESI Cloud platform) - The validity of the inputs (recognised patterns) is checked based on the defined rules– see above two options for Stimulus - Transforms the partners in information needed by the operators and shop floor managers and presents them over GUI (which may include graphics etc.) - Allow the user to request and get additional information related to the potential and/or predicted problems
	Functional Requirements	The solution shall: - Check validity of the inputs (recognised patterns) based on the defined rules– see above two options for Stimulus - Provide the Operator with the useful information to react in advance in case of predicted anomalies - transform data analytics results into information usable by the operator - Allow the user (operator) to get information on patterns in the current process which may lead to problems. - Assists the user (operator) to get information on 'similar' processes and moulds and compare them - Allow the user to request and get additional information related to the current process (t. b. d.)

		The solution shall in set-up mode: - Offer possible predictions and status information to the user - Allow the user to select which predictions and status information conditions should be activated and sent to her/him - Administrator set-up: may define/change rules to identify if the patterns indicate possible problems in the manufacturing process or not – see above options for Stimulus
External Interface Requirements	*User Interfaces*	- The solution provides in the form which is suitable for the operator (user) - Information to the operator can be presented to other users, e. g. shop floor manager and for each user the presentation of the information at GUI are adjusted to her/his needs GUI may include various graphical presentations upon user request In set-up mode: GUI will present the list of possible information and prediction of the status of the processes and the user may select which information and predictions are relevant for her/him. The GUI must allow overview of all relevant info – so minimal information (but include information to understand what the status really is) Administrator set up: GUI presents set of defined rules in the form IF … THEN … to identify if the pattern(s) may indicate potential problems in the production line and allows the administrator to select the rules to be applied and or add new rule
	Hardware Interfaces	This module/feature shall not have direct interface with HW components, the data sources
	Software Interfaces	Directly interfaced to Data Analytics Module – INENDI and ESI Cloud platform – see above The graphical features of INENDI Inspector shall be used for graphs etc.
	Communications Interfaces	Specify the various interfaces needed for communication with other software/hardware components
Performance Requirements		- The solution includes all data the user (operator) needs to identify the problem and decide on further actions - The solution provides all information the user (operator)needs to identify condition of the current process - The solution provides feedback (condition monitoring) from manufacturing processes in a form which easy to use by the operator - The time response
Other non-functional requirements		- The solution is in compliance with the VW standards - The solution assures security of data collected – no data leaks and access by unauthorised actors

2.3.3.7 Design Assistant Module

Table 2-12 Design Assistant Module

ID	Vw-DAM-1	
Business requirement reference	- BOOST 4.0 provides approaches to assist mould designers by provision of feedback from manufacturing processes and from vehicles in use (feedback related to the light metal parts). - BOOST 4.0 provides approaches to assist mould designers in the creation of moulds with a higher durability. - BOOST 4.0 provides approaches to assist mould designers in the creation of moulds with a lower rejection rate. - BOOST 4.0 provides approaches to assist mould designers to reduce the time for a mould design. Using of the BOOST 4.0 solution will be time effective for the designer (in total). - BOOST 4.0 provides approaches to assist mould designers which reduce the costs of a mould. - The solution allows to trace back the identified problems with light metal parts with the part and mould design and light metal part casting processes. - The solution allows to use data from garages on problems with light metal parts in vehicle use.	
Overall Description	*SW Module: Design Assistant Module* The software provides the designer with data on status of the production processes and prediction on (potential) problems in manufacturing process, as well on problems with light metal parts at the vehicles in use. The software module gets from the Data Analytics Module the patterns identified in the data streams from the manufacturing processes (machines, moulds) and the patterns are presented in the appropriate forms to the users (designers) aiming to provide information on the status manufacturing processes. The designer gets information from garages on problems with light metal parts at the vehicles on use as well as information on vehicles at which the problems had (may) occur (data streams from vehicles over Data Marketplace) The objective is to allow for reaction to potential predicted problems based on continuous tool condition monitoring Through more available information/data from moulds and machines and vehicles in use, a more appropriate reaction (re-design) is possible based on observed parameter which are currently hidden. - Assistant systems provide information useful to optimise parametrisation of the light metal casting process.	
Feature	*Introduction & Purpose of feature*	***Design Assistant Module:*** The feature assists the designer to get comprehensive overview of the status of the casting processes problems and on use of light metal parts in vehicles and react on (potential) problems in manufacturing process

		and parts in use (e. g. by re-design, take into account when designing new parts and moulds etc.)
	Stimulus *Response* *Sequence*	Input & output description Input: Recognised data patterns in data flowing from manufacturing processes (from the Data Analytics module) Prediction of the process and tools status (ESI Cloud platform) Direct feedback on light metal parts from garages Recognised data patterns in data flowing from vehicles I in use (from the Data Analytics module – INENDI Inspector, data coming from Data Marketplace) Data on context of the vehicles in use at which the problems with the light metal parts are recognised (from the Data Analytics module – INENDI Inspector, data coming from Data Marketplace) Output: Data on current status of the manufacturing processes and vehicles in use over GUI Stimulus: The pattern in data flow from the manufacturing processes (machines, moulds) and/or vehicles in use is identified by the Data Analytics module. The possible problems are predicted by the simulation Two options: - Analytic Modules (ESI cloud platform) continuously sends the information on patterns and predictions - The user requires patterns and/or predictions – to get info on the current status of the production lines The information from garages indicate problems Response: The Design Assistant transforms the patterns in information needed by the designer and presents them over GUI (which may include graphics etc.) Sequence: - Identified data patterns coming from the Data Analytics module (see options above) - Data patterns may be used to predict state of the processes and tools (ESI Cloud platform) - Data from garages on vehicles on use are provided - The validity of the inputs (recognised patterns, input data) is checked based on the defined rules– see above two options for Stimulus - Transforms the partners in information needed by the designers and presents them over GUI (which may include graphics etc.) - Allow the user to request and get additional information related to the current patterns in manufacturing processes and/or vehicles in use - Allows to correlate data from garages with data streaming from the vehicles

	Functional Requirements	The solution shall: - Check validity of the inputs (recognised patterns) based on the defined rules– see above two options for Stimulus - Provide the designer with the useful information to react in advance in case of predicted anomalies - transform data analytics results into information usable by the designer - allow the user (design) to get information on patterns in the production processes which may lead to problems as well as on patterns on state of light metal parts in vehicles in use - assists the user (operator) to get information on 'similar' processes and moulds and compare them - Provide the feedback from garages on light metal parts to the designer in suitable form (t. b. d.). - Allow to correlate the feedback from garages on problems with light metal parts during the vehicle use with data streams from vehicles. - Present the identified patterns to the designer in suitable form (t.b.d.). - Allow to analyse condition (context) under which the problems with light metal parts occurred. - Allow the user to request and get additional information related to the current process and vehicles in use (t. b. d.) - Assist the user (designer) to get feedback on 'similar' parts and moulds when designing a new mould/part - Assists the designer to get feedback which is relevant for the mould under re-design (if available) The solution shall in set-up mode: - Offer possible predictions and status information to the user - Allow the user to select which predictions and status information conditions should be activated and sent to her/him - Administrator set-up: may define/change rules to identify if the patterns indicate possible problems in the manufacturing process and vehicles in use or not
External Interface Requirements	*User Interfaces*	- The solution provides in the form which is suitable for the operator (user) – t. b. d. - The feedback from garages on light metal parts is presented to the designer in suitable form (t. b. d.). - Information to the operator can be presented to other users, e. g. shop floor manager and for each user the presentation of the information at GUI are adjusted to her/his needs GUI may include various graphical presentations upon user request

		In set-up mode: GUI will present the list of possible information and prediction of the status of the processes and light metal parts at vehicles in use and the user may select which information and predictions are relevant for her/him. The GUI must allow overview of all relevant info – so minimal information (but include information to understand what the status really is) Administrator set up: GUI presents set of defined rules in the form IF … THEN … to identify if the pattern(s) may indicate potential problems in the production line and/or vehicles in use and allows the administrator to select the rules to be applied and or add new rule
	Hardware Interfaces	This module/feature shall not have direct interface with HW components, the data sources Direct interface to the Data Marketplace
	Software Interfaces	Directly interfaced to Data Analytics Module – INENDI and ESI Casting Simulation Suite – see above The graphical features of INENDI shall be used for graphs etc. Direct interface to the Data Marketplace
	Communications Interfaces	Communication with garages
Performance Requirements		- The solution includes all data the user (designer) needs to identify the problem and decide on further actions (e. g. re-design etc.) - The solution provides feedback from manufacturing processes in a form which easy to use by the designer - The solution shall assist the designer to get feedback which is relevant for the mould under re-design (if available) - The time response
Other non-functional requirements		- The solution is in compliance with the VW standards - The solution assures security of data collected – no data leaks and access by unauthorised actors

2.3.4 Design decisions

Table 2-13 Major design decisions in trial 1

ID	Description	Justification	Relevant system requirements
1	VW Data Infrastructure	To provide data from production processes.	
2	CPS Data Marketplace (ATB)	To provide data from vehicles.	
3	ESI Cloud platform	To provide support in casting and mould design	

		It may be used for health prediction models.	
4	INENDI Inspector (ESI)	To process big data needed for predictive maintenance and improved simulation and design.	
5	VW Connector to EIDS	To provide connection to EIDS to integrate data from various subsidiaries and suppliers.	
6	Manufacturing Process Warning	To warn operator and shop floor managers on possible problems in casting processes.	
7	Design Warning	To warn designer on possible problems in casting processes and/or vehicles in use.	
8	Simulation models updates based on big data analytics and process change	To update simulation models and parameters based on analytics of big data streaming from production processes or based on changes in the production process.	
9	Data selection method	To allow effective selection of data needed for the stated objectives.	Method and tool in off-line mode

Table 2-14 Components used in trial 1

Component ID	Component Name	System Requirement References	Comments
N/A	VW Data Infrastructure	Supports all requirements	Parallel VW project Industrie 4.0 Legacy system
VW-DM-1	CPS Data Marketplace	Data Marketplace	
BC-ESI-1	ESI Cloud platform	BOOST 4.0 provides simulation tool health prediction models. BOOST 4.0 simulation tool health prediction models are optimised with real data coming from machines and	

		moulds in the light metal casting process. Data from machines are analysed using big data analytic tool(s) to identify feedback in form needed for design of moulds and parts.	
BC-ESI-2	INENDI Inspector (ESI)	Data from vehicles are analysed using big data analytic tool(s) to identify feedback in form needed for design of moulds and parts. The data analytics tool(s) identify patterns in data streaming from the vehicle relevant for the possible problems with the light metal parts. The solution allows the user (operator) to detect potential problems in the processes.	
VW-C-1	VW Connector to EIDS	VW Connector to EIDS	
VW-MPW-1	Manufacturing Process Warning	e. g. Manufacturing Process Warning	These two components may be combined as the include high amount of equal functionalities
VW-DW-1	Design Warning	Design Warning e. g.	Main difference to previous component
VW-DSM-1	Data selection method	Data selection method	
VW-MAM-1	Maintenance Assistant	Assistant systems provide information useful for failure avoidance. Assistant systems provide information useful for predictive maintenance. BOOST 4.0 provides an approach to provide processed data as real-time	

		monitoring assistant system in production. The Operator gets useful information to react in advance in case of predicted anomalies. BOOST 4.0 provides approaches to assist machine operators in increasing the process transparency. BOOST 4.0 provides approaches to assist machine operators to gain knowledge about what is happening in the light metal casting process (including e. g. history over time period). BOOST 4.0 provides approaches to gain knowledge of operators about the light metal casting process. BOOST 4.0 provides approaches to reduce the rejection rate through data analytics in the light metal casting process. BOOST 4.0 provides assistant systems in production which transform data analytics results into information usable by the operator. BOOST 4.0 provides approaches to react in advance on upcoming failures to avoid process disturbances. BOOST 4.0 provides approaches to reduce the maintenance time needed for a mould in the light metal casting process. The solution provides all information the user (operator) needs to identify condition of the current process.	

		The solution allows the user (operator) to get information on patterns in the current process which may lead to problems. The solution assist the user (operator) to get information on 'similar' processes and moulds and compare them The solution provides feedback (condition monitoring) from manufacturing processes in a form which easy to use by the operator.	
VW-DAM-1	Design Assistant	Design Assistant	

3 Trial 2: FILL Gurten

The section consists of two main parts and provides details for trial 2:

1. **Pilot overview**

Provides explanations about the manufacturing processes and plants involved in the trial. Additionally, it explains the objectives to be achieved and the partners involved.

2. **Business requirements**

This section provides an overview of the business processes involved in the trial.

3. **Pilot specification**

Details the technical specifications required in order to realize the solution for each trial. This includes descriptions of legacy systems to be integrated, software components, and software requirements.

3.1 Pilot overview

3.1.1 General description

The **FILL pilot** is about a lot-size-one machine tool circular engineering in a factory 4.0. FILL as key machine tool provider delivers in the order of 100 production systems per year to around 50 customers worldwide. 90% of FILL machines and systems are exported to automotive, aerospace, sports, construction and housing and renewable energy sectors. Zero defect production demand that machines cost-effectively flexibly adapt to optimum production configurations. Therefore, Machine tools are increasingly customized-customizable (lot-size 1 production scheme). Rigid engineering processes designed for mass production are not able to optimize smart connected machine tool lot-size 1 engineering and fail to incorporate external operational data to optimize machine self-configuration and adaptation features.

Most of the IoT (Internet of Things) and Big Data platform approaches focus on operations and not on the engineering process of the production systems. The Trial will close the loop to the engineering process. Currently, to make data usable for the suppliers engineering process, the customer has to prepare the data elaborately and send it manually to the supplier. As the production systems are highly customized, the data structure is not standardized. So, to use the data an extra post-processing is necessary.

Within the FILL trial the focus of implementation will be the following:

1. Big Data pipeline architecture

2. Modern and connected engineering management tools
3. Networked engineering (engineering data and models)

Table 3-1 Trial 2 application domains

Application Domain*		Description and justification of the application domain
Smart Digital Engineering	X	See in section 3.1.2 the paragraph Benefits in the engineering process for machine producer
Smart Maintenance & Service	X	1. Optimization of the quality and service life of the machines 2. Optimization of maintenance times and cycles 3. Reduction of downtime 4. Improvement of the quality of the products produced on the machines 5. Derivation of new business models for service and maintenance

3.1.2 Objectives

The objective of the FILL trial is a general engineering approach for highly flexible machines manufacturing optimization.

- **Model-based and big data-driven engineering process**, analyse engineering data and operation data for quick identification of unattained requirements and design faults, completion of design studies and new machine designs.
- **Machine and Process Models Optimisation Engine** for production plants reconfiguration and reduced design efforts with big data analytics over distributed data (dynamic machine data, part information, engineering data).
- **Machine Big Data Logger and Exchange Platform**. OPC UA and TSN based open hybrid fog node and cloud computing infrastructure for data exchange between different machines within and across different factories.
- **Connected 3D Production Simulation**. Digital twin manufacturing configuration virtual validation/visualisation and productivity optimisation using pre-existing and real time data from different factory levels (small cell to entire factory).

Benefits in the engineering process for machine producer:

1. **Quality improvement**
    a. Better achievement of customer requirements
    b. Higher level of maturity after engineering phase
    c. Less difference between the planned (as engineered) and the built (as built or as manufactured) production system
    d. Possibility to check if the production system is used according to the specification
    e. Less design failures
2. **Time (mainly throughput)**
    a. Due to the frontloading time saving effects are expected in the later life cycle phases (e. g. commissioning Phase)
    b. High and fast data availability and correct linkage between engineering data and machine/production data leads to quicker findings during clarification and specification phase
    c. Simplification of the reusability of engineering data
3. **Cost effects due to**
    a. shorter throughput time – reducing time to market
    b. Increased delivery reliability
    c. More office work, less on-site work (suboptimal working conditions)

Benefits for the customers:

1. Optimization of the quality and service life of the machines
2. Optimization of maintenance times and cycles
3. Reduction of downtime
4. Improvement of the quality of the products produced on the machines
5. Derivation of new business models for service and maintenance

3.1.3 Participants

You can find an extended description for each of the participant in APPENDIX 1: Participant description

Table 3-2 Trial 2 participants

FILL	FILL One of the world's leading ideas manufacturers for production systems in the fields of automotive, aerospace, sports, energy, wood & construction	Main partner of the pilot

TTTech	**TTTech** TTTech is the innovator of Deterministic Ethernet and the driving force behind the IEEE TSN standard and SAE Time-Triggered Ethernet standard	Brings its Fog Node architecture as backbone for the trial Will further develop its Fog Node as a multi-purpose device for factory automation
VISUAL COMPONENTS	**VISUAL COMPONENTS** Is a leading developer of software for 3D Manufacturing simulation, and develops solutions for the industrial automation community.	Contributes with its knowledge and expertise in factory simulation and visualization technologies Also involved in the standardization initiatives as a member of the IEC SC65E committee
RISC Software GmbH	**RISC Software GmbH** Is an internationally recognized IT company, which combines mathematics and computer science to develop individual software solutions in interdisciplinary teams for science and industry.	Specializes in data collection and processing frameworks that collect, process, and analyse data, with forecasting and data stream simulation an important component

3.2 Business requirements

This section specifies the business requirements that the novel FILL solution that is implemented as part of the BOOST4.0 project must meet. We first specify a list of objectives, which eventually enable FILLs new Big Data Powered Business Processes:

List of objectives:

- <u>Long-term reduction of machine development times</u>

  First to market with the leading edge technology on smart engineering on industrial big data, FILL will become the leading smart machine builder. Reducing time-to-market of innovative customized products is a key success factor for industrial companies. Integrating big data feedback information from operation and maintenance phases into the engineering phases will shorten the time for real plant or factory commissioning in lot-size-1 production facility. With regard to the life cycle, this consideration also

includes optimization potentials with regard to delayed requirements and rework. All this aims to strengthen the urge to transform towards an agile organization.

- Establish pattern and anomaly detection framework

In the new proposed engineering methodology for model-based and big data-driven engineering processes it is essential to establish a pattern and anomaly detection framework (connected to the results of WP2-WP3). With this framework different behavior models as well as artificial intelligent and machine learning algorithms are developed. The models are used in the engineering process to get better insights of the physical, logistics or other behaviors. This will accelerate the decision-making process, reduces or accelerate iterations in all domains of the engineering and therefore improvements in the sense of time, quality and costs. The models are stored in a model repository and can be further used by the customer, e.g. as virtual sensors. This could lead in a new business model "Model as a Service".

- Integration and synchronization of machine, product and process data

In the early phases of the engineering process, mainly in the conceptual phase, usually many data sources are required in order not to overlook any boundary conditions and requirements. The integration and synchronization of different data coming from different data sources is an enabler for establishing the smart digital engineering process using big data. In sense of Big Data Analytics this will improve the informative value of the analysis output, the quality of the developed models and increases the model diversity. This needs knowledge from different ICT topics like interfaces (OPC UA, MQTT, RT), data management (sql, nosql, hybrid) and so on. This objective is based on the results of WP3.

- Simulation - PLM integration

To use the large number of CAD-Models efficiently, interfaces between Visual Components simulation tools and the engineering management tools of Fill have to be established, thus a better integration of the simulation process into the proposed engineering process will be achieved. This leads to a simulation management in which saving, loading and version control are well integrated. Moreover, design changes will be updated faster in the simulation. The target from VIS is to create a generic PLM interface and tailored with add on for the PLM solutions in the market.

- Developing of Digital Twins

Depending on the application and task, different digital twins will be developed. However, the main objective will be to map the different states of the production system or parts of it over the life cycle. In this case we will focus on three states

- as-engineered (state after the engineering was finished)

- as-manufactured (state after manufacturing and in-house commissioning)
- as-operated (how the customer operates the production system, simulate historical real data)

In order to extend the field of application from pure simulation and monitoring usage, the requirements have to be integrated into the digital twin. This enables,

- requirements analysis for new projects
- failure analysis by comparing the three states
- decision making during the engineering process

- Customer centric outcome

The development of innovative, highly customized production systems is generally based on a customer-centric approach. Furthermore, for the machine builder, the operations process knowledge is a key success factor. This is mostly expertise and empirical knowledge and is usually built up during the operating phase and used in follow-up projects. The intended feedback loop should accelerate the build-up of knowledge and make it possible to secure customer wishes earlier and increases customer satisfaction. This leads to fewer delays in the business process like the customer dependent approval processes, e.g. design approval, delivery approval etc. and in the following to earlier cash flows which are linked via a payment schedule to the approval process.

- Human resource development

A key factor in the implementation of such far-reaching strategic business objectives are the right employees. Especially in the traditionally conservative area of special machine builders, new methods and technologies are only slowly gaining acceptance. Moreover, a machine builder is not seen as a potential employer on the ICT job market, so finding ICT talents is very difficult. Actions must be taken to increase the company's visibility to ICT talents (developing recruiting strategy).

Actions:

- State of the art advertisements for IoT-Architect, Data Scientist, etc.
- Marketing measures at trade fairs (extra area for ICT), in journals, etc.
- Offering master and bachelor theses

The outcome of these objectives must be the following four new business processes:

- BP 1 - Agile model management & development process
    a. Digital asset repository
    b. Big Data (IoT)

- BP 2 - Data analytics process
    c. Data processing pipelines
    d. Data exploration, model integration and deployment
- BP 3 – Service development process
    e. Extending Fill business model by Digital services (Model as a Service)
    f. Smart Maintenance
- BP 4 – Simulation based release process
    g. IoT Data and simulation driven engineering (using real historic data)
    h. Virtual Commissioning

3.3 Pilot specification

This section details the technical specifications required in order to realize the solution for trial 2. The section is organized in three sub-sections:

1. **Legacy systems**

   This sub-section provides an overview of the existing software system at FILL. As part of BOOST4.0, FILL will develop a new big data ecosystem that will replace the existing solution on the long term.

2. **Components and infrastructure**

   This sub-section outlines the new big data ecosystem

3. **System requirements**

   This sub-section provides an overview of the features required to implement the new big data ecosystem.

4. **Design decisions**

   This sub-section details the design decisions made until time of writing this document.

Fill GmbHs legacy software framework for communication and data exchange with machines in factories is called *Machine Workflow*. This framework provides an application programming interface (API) that abstracts two communication protocols: OPC DA and a proprietary PLC communication protocol. Software routines for controlling and accessing the machines are implemented as so called "workflows" in this framework. Fill GmbH used Machine Workflow as a basis for individual software solutions for customers. However, Fill GmbH discontinued the development of *Machine Workflow* and replaced it with *Fill Cybernetics* recently.

Fill Cybernetics is feature compatible with Machine Workflow but improves in various aspects:

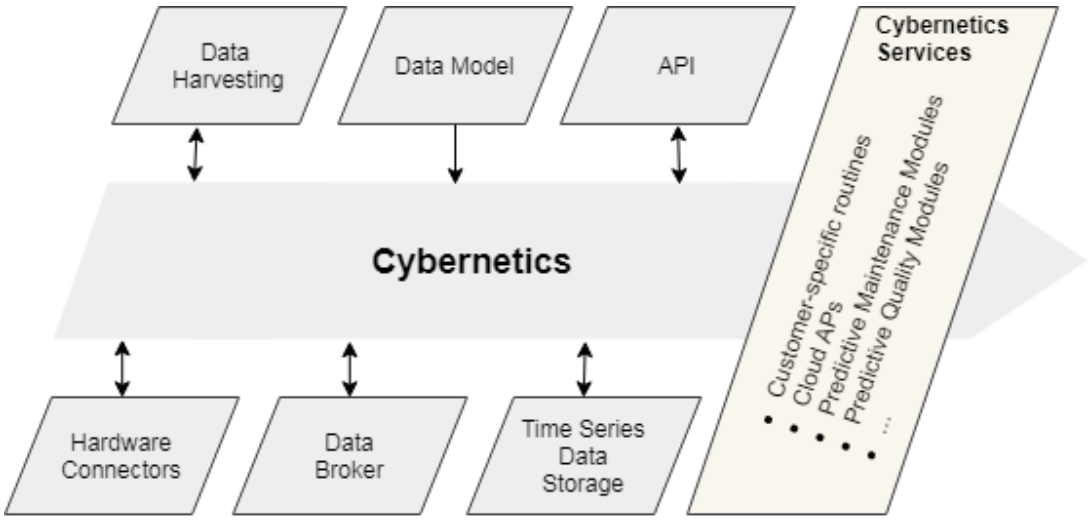

Figure 5: Cybernetics Overview

- *Machine Workflow* is a framework for machine communication only. It wraps communication protocols (e.g. via OPC DA) and allows implementing routines that control machines and factories.

  Customer projects and required features (e.g. for data logging or machine control) have to be implemented from scratch. Machine Workflow lacks default features for data harvesting, distribution, analysis, or persistence (e.g. cloud connectors for big-data applications).

  Cybernetics is modular and extensible Industry 4.0 platform that provides different connectors to machines (left part of Figure 5: Cybernetics Overview). It reads data from machines, and represents them using the Cybernetics data model (middle part of Figure 5: Cybernetics Overview). Eventually, it publishes the data on a customer-owned data broker. Cybernetics features a time-series data storage and stores every individual data stream. It also provides a rich API for implementing Cybernetics Services. These services can implement various features, such as customer-specific routines to control the machines in a factory, cloud access points, predictive maintenance modules (e.g. in the form of remote services as provided by RISC), or predictive quality modules.

  There are two kinds of Cybernetics Services: Fill-customer-specific services (they implement the business logic of Fill-customers and control the machines) and Fill services (general and reusable services, e.g. cloud access points, predictive maintenance modules, …).
- *Machine Workflow* is a monolithic, historically grown application and imposes a high coupling between new features and the machine workflow code. This technical depth makes development of new features slow, error prone and therefore expensive.

In *Cybernetics,* features are reusable services without coupling to Cybernetics internals. Also, a Cybernetics system can be set-up as a distributed, fail-save software system. E.g., a Cybernetics system can be distributed across different servers on the customers premise or hosted as a cloud service. The Cybernetics API makes implementation of new services fast and easy, which reduces development costs of new features.

- *Machine Workflow* does not define a data model for data exchange between different software routines, machines, factories, or other software instances. Data models for customer projects were designed from scratch within each project and therefore also always reflect the customer requirements and are not unified across different projects. Data harvesting of Fill product lines and comparing this data across different customers was not intended. Machine Workflow is only intended to log data in a customer-specific format and stores them into SQL data bases.
  Cybernetics defines a data model, which is used for every data point that is read from hardware. This unified data format with additional metadata allows relating values with their origin, comparing values across different projects, and storing them in a unified format.
- *Machine Workflow* is an encapsulated offline-only software system. It is designed for an on-premise-usage without connectors to online (e.g. cloud) services. *Cybernetics* can be set up as a small service on a field PC, on a distributed server infrastructure on the customers premise as well as a cloud service. Various connectors (implemented as Cybernetics services) connect it to other systems.

As part of the Boost 4.0 project, no Machine Workflow application will interface with the Boost 4.0 platform. For completeness, the following table describes Fill *Machine Workflow*.

3.3.1 Legacy Systems

Legacy system name			Fill Machine Workflow
Type			Framework for PLC communication via OPC DA or a proprietary PLC communication protocol.
Details	*APIs*		API for synchronous data exchange with a PLC.
	Data	*Description*	y data point that a PLC wants to change with the software.
		Format	No data format. Values are directly exchanged between PLC and a Machine Workflow application.
	Data Source (distributed/centralized)		Centralized. Data always originates from a PLC.

Big Data Characteristics (if applicable)	*Volume (size)*	Data exchange rates vary between 1 byte / min – 1Mbyte / sec
	Velocity (e.g. real time)	Machine Workflow does not offer real-time capability. Machine Workflow offers synchronization primitives.
	Variety (multiple datasets, mashup)	The data format/datasets vary between different projects. No standardized data format available.
	Variability (rate of change)	High variability: Machine workflow applications implement customer requirements only. No infrastructure available to feed data back in Fills upcoming Big Data infrastructure.
Other Big Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*	--
	Visualization	In almost any Fill Machine Workflow project there were data visualization features. However, they only visualize production and machine data reflecting the Fill customers' requirements.
	Data Analytics	There were no projects with data analytics capabilities.

3.3.2 Components and infrastructure

ID		BC-Fill-1
Responsible partner		Fill GmbH
Tool name		Fill Cybernetics
Overall Description		Fill Cybernetics it the industry 4.0 platform of Fill. A Fill Cybernetics system is hosted by the Fill customer (on a field device, server infrastructure, or as a cloud service) and runs the data harvesting, data distribution, and customer-specific services.
Details	*Functionalities offered*	Data harvesting connectors are a core component of Fill cybernetics. They interface to machines, sensors, PLCs, 3rd party systems etc. and collect all relevant data form a machine or factory. These data is available via a data broker within Fill Cybernetics. Fill Cybernetics allows the implementation of services, which process, analyse, or store this data. Services are implemented using the Cybernetics API. There are default services for, e.g., data logging, outlier detection, experimental predictive quality services, experimental predictive maintenance services etc.

			Depending on the Fill costumer's requirements, new services are implemented.
	Data input	*Description*	Distributed. Fill Cybernetics can collect data from any sensor or PLC that is integrated using a dedicated connector. For example, this data includes: machine data such as temperature, power,… as well as production data such as quality measurements, production figures, … Also, custom connectors allow Fill Cybernetics to interface to other services (implementation effort required).
		Format	Within a Fill cybernetics system, data is exchanged as a JSON object using the Fill data model. This data model allows Cybernetics to relate values to their origin (using metadata such as time, origin, unit, …). Cybernetics services can transform data to different models and exchange it with 3rd party software/services.
	Data Output	*Description*	Any data object (e.g. a sensor value, machine data, production data) that is collected by Fill cybernetics can flow between Cybernetics services, as well as to other 3rd party services (e.g. cloud services of research partners). When data objects escape the Fill Cybernetics boundary, custom connectors allow transforming them to a given target format.
		Format	Within Cybernetics: JSON Custom connectors allow transforming data objects to given 3rd party formats.
	Integration requirements		Fill GmbH plans to use PTCs Windchill as a PLM system, To integrate data from the field (i.e., a Cybernetics system) into Fill's engineering process (Windchill), Fill plans to use PTCs Thingworx IoT platform.
	BDVA mapping		There are Visualization services that can visualize specific sensor values. Also, we are using Grafana to visualize the data stored in Cybernetics time series database. New visualization capabilities are being developed with our research partners. Simple data analytics Cybernetics services are already in use (e.g. to detect unusual patterns and predict machine failures). These services are still under heavy development and not ready for real world application. Currently, we are working on new data analytics services with our research partners. If applicable indicate BDVA model mapping: 1. Data Visualization & user interaction 2. Data processing 3. Data Analytics

		4. Data Management 5. Data sharing platforms 6. Development – Engineering and DevOps 7. Communication and Connectivity 8. Cybersecurity and Trust *Note: More than one may be applicable*

3.3.3 System requirements

In this section we list requirements that the FILLs big data platform must meet. The requirements are software requirements in terms of features addressing the business needs of trial 2. The details include, associated business requirements, an overview of the functionality, data input/output, relevant software requirements of the feature, interfaces, performance and other non-functional requirements.

Table 3-3 Software requirement SR-WP5-T5.1-1

ID		Fill-R1
Business requirement reference		Software platform for efficient data mining.
Overall Description		The big data platform (Fill Cybernetics) must enable efficient data mining with multiple lot-size-one machines.
Feature	*Introduction & Purpose of feature*	Fill Cybernetics needs interfaces to different machines and a backend that can store and process the machine data of different machines.
	Stimulus Response Sequence	Data analysis components on top of Cybernetics can then analyse data.
	Functional Requirements	• System shall be able to connect to different Fill machines • System shall be able to store machine data (up to 1000 data points per machine per second) • System shall be able to mine high frequent machine data (up to 100 data points per machine every 6 ms) • System shall be able to store machine data and alarm data in time series databases • Additional Cybernetics modules shall be able to access this data for advanced analysis
External Interface Requirements	*User Interfaces*	The system shall offer a user interface (dashboard) that allows users to visually analyse machine data with little effort
	Hardware Interfaces	The system shall be able to connect to Fill machines via OPC UA and Profinet (hardware bus)
	Software Interfaces	The system must be able to connect to PLM system (PTC Windchill).

		The system must be able to connect to ERP and CRM software
	Communications Interfaces	The system must be able to connect to time series databases as well as document databases
Performance Requirements		• System shall be able to store machine data (up to 1000 data points per machine per second) • System shall be able to mine high frequent machine data (up to 100 data points per machine every 6 ms)
Other non-functional requirements		None

ID		Fill-R2
Business requirement reference		Digital Twin
Overall Description		The big data platform (Fill Cybernetics) must enable the implementation of digital twins.
Feature	*Introduction & Purpose of feature*	Fill Cybernetics needs APIs that allow the implementation of digital twins (e.g. a digital twin of a real Fill machine implemented in Visual Components).
	Stimulus Response Sequence	A digital twin allows in depth analysis of Fill machines in a virtual environment.
	Functional Requirements	• System shall be able to provide machine data to drive a digital twin • The system shall be able to integrate software sensors, used or implemented in 3rd party systems (e.g. Visual Components)
External Interface Requirements	*User Interfaces*	None
	Hardware Interfaces	None
	Software Interfaces	Fill Cybernetics must interface with various simulation software (e.g. Visual Components). Fill Cybernetics must implement APIs that ease the effort of implementing digital twins.
	Communications Interfaces	None
Performance Requirements		• Performance requirements are not yet defined; these requirements depend on the individual implementation of digital twins.
Other non-functional requirements		None

ID		Fill-R3
Business requirement reference		Smart digital engineering.
Overall Description		The big data platform (Fill Cybernetics) must enable smart digital engineering within Fill.
Feature	*Introduction & Purpose of feature*	Machine data from existing machines must be available during the engineering process and the design of new machines.
	Stimulus Response Sequence	Fill Cybernetics and big data of Fill machines should enable a simulation based release process.
	Functional Requirements	• Fill Cybernetics must be integrated into the engineering process of Fill • Existing/historic machine data (digital experience) must be available during engineering of new machines • Historic machine data must enrich and improve simulations of new machines.
External Interface Requirements	*User Interfaces*	No dedicated UI; integration in engineering tools.
	Hardware Interfaces	None
	Software Interfaces	Interfaces to engineering tools: Integration into PTC Windchill. Other tools are not yet defined.
	Communications Interfaces	None
Performance Requirements		None
Other non-functional requirements		None

3.3.4 Design decisions

ID	Description	Justification	Relevant system requirements
D1	Time series databases	Special purpose DBs (TSDBs) are most suited for machine data	
D2	PTC Windchill as a PLM system	Open architecture that allows integration with Fill Cybernetics	

4 Trial 3: VWAE real-time self-learning virtual factory 4.0

The section consists of two main parts and provides details for trial 3:

1. **Pilot overview**

Provides explanations about the manufacturing processes and plants involved in the trial. Additionally, it explains the objectives to be achieved and the partners involved.

2. **Business requirements**

This section provides an overview of the business processes involved in the trial.

3. **Pilot specification**

Details the technical specifications required in order to realize the solution for each trial. This includes descriptions of legacy systems to be integrated, software components, and software requirements.

4.1 Pilot overview

4.1.1 General description

With this pilot we intend to:

- Establish automatic warehousing (put away and picking) and automatic delivery to commissioning area (SUMA)
- Establish interactive sequencing environment between the commissioning area and replenishment of the new material at downstream with the delivery of sequencing material to the assembly line, based on the orders obtained from the manufacturing execution system. The sequencing system already allows Volkswagen Autoeuropa to place parts in the correct sequence to assemble at the point of fit. The parts arrive at the sequencing cell and are placed in the correct order by which they are to be assembled. The rack to be transported to the point of fit contains all the types of parts required in the sequence by which the vehicles appear to be mounted on the assembly line.

With the automation of these handling processes and interaction between them, Volkswagen Autoeuropa will be able to automate the entire handling process, from the warehouse to the assembly line, including the process of sequencing and transporting the rack to the point of fit in the assembly line. In addition, the solution will be developed according to the Industry 4.0 paradigm guaranteed that the system is flexible, composed

of autonomous components intelligent and interconnected to each other, to ensure that the system is highly modular and reconfigurable into the existing framework.

As far as the innovation related to this project is concerned, it will be focused in the realization of a sequencing cell capable of automatically organize the parts, according to the stipulations of the manufacturing execution system and delivery to production line side.

Table 4-1 Trial 3 application domains

Application Domain*		Description and justification of the application domain
Smart Production Planning & Management	X	Digital twin which mirrors the real logistics: + replicates the current logistics + new logistics alternatives are tested before implemented Verification and validation in VR before implementation
Smart Operations & Digital Workplace	X	Collection of data and virtualization of information. Data needs to be processed to give the user context and meaning.
Smart Connected Production	X	All process data will be digitally available and linked to the entire manufacturing system. The algorithm must be ready for real time updates and adjustments.

4.1.2 Objectives

With the dawn of industry 4.0 and its technology breakthroughs, one can assume the coming years as vital for the implementation of some type of autonomous warehouse deprived of any human interaction with smart communications between each machine. For those reasons, Volkswagen Autoeuropa hereby pledges its commitment to instrument such a concept with the project presented within the BOOST4.0 consortium.

The goal of this project is to take advantage of the latest technology developments and apply it in an industry environment with non-stop cycles and with high up times. In the end, the desirable target is to transform an environment overwhelmed with manual complex processes with one that brings modular flexibility and automation.

The expected benefits with the implementation of an autonomous warehouse would translate into financial benefits for the Volkswagen Group, increase in flexibility (which is key specially during the introducing of a new model), improved ergonomic conditions for

operator, minimization of human dependency for manual operations and thus an increase in the process efficiency.

- **Financial benefits:** the current warehousing process has inefficiencies mainly because a warehouse deprived of any automation capability is more likely to occupy additional space due to shelve specification (vertical space usage and possible reduction in the aisle size). Furthermore, the current process is highly vulnerable to damages caused by the operational equipment which in turn are required to be manoeuvred by highly skilled operators.
  All of these issues from the current process count as inefficiencies to the organization.
- **Flexibility:** any industry is highly exposed to external and internal factors of entropy but none is so much exposed to unpredictability as the automotive industry. Automakers are constantly forced to make changes to their products in order to adapt to clients requirements. Therefore, manufacturing processes need to have a mind-set geared towards modular flexibility where change can happen with ease and promptly. The Volkswagen group strongly reinforces this idea onto the corporation's core as it is believed this feature is critical to the company's success.
- **Ergonomic conditions:** dealing with a difficult and complex process on a daily basis comes at a price for the operators; predictably the operator's health and performance is directly affected. With the implementation of an automated warehouse all the heavy work relies on the machines thus creating a pleasant working environment.
- **Human dependency:** any system which relies on direct human supervision and human operational control is highly susceptible to error. This type of concept nearly removes this factor of the equation; every component of the system is controlled by systems specification. The biggest winners of this affair will be the plant's efficiency and production.
- **Increase in the process efficiency:** the automation and control of the process through a centralized database enables for a business intelligence approach to the warehouse system. Tools such as reporting and KPI's offer the opportunity to analyse and improve the system with real time data (on-line material flow such as unit load movements/sequencing and operation/fleet management).

4.1.3 Participants

You can find an extended description for each of the participant in APPENDIX 1: Participant description

Table 4-2 Trial 3 participants

Volkswagen	VOLKSWAGEN AUTOEUROPA Manufactures the Sharan and T-Roc models for Volkswagen and the Alhambra for SEAT in Palmela (Portugal)	Main partner of the pilot
UNINOVA	UNINOVA Multidisciplinary, independent and non-profit research institute, whose main aim of UNINOVA is to pursue excellence in scientific research, technical development, advanced training and education.	Will provide expertise in the domain of the Big Data interoperability and analytics
VISUAL COMPONENTS	VISUAL COMPONENTS Is a leading developer of software for 3D Manufacturing simulation, and develops solutions for the industrial automation community.	Contributes with its knowledge and expertise in factory simulation and visualization technologies Also involved in the standardization initiatives as a member of the IEC SC65E committee
ASTI	ASTI Is an international company involved in engineering and development of made to measure solutions for logistics.	Contributes by adapting the AGV and their control system to the requirement of the pilot.
Telefónica	TELEFONICA I+D Is the innovation company of the Telefonica Group. It contributes to the group competitiveness through technological innovation.	AGV communication improvement Validation over 5G Network

4.2 Business requirements

This section specifies the business requirements that the solution that will be implemented in this pilot must meet:

- Provide the logistic teams with better planning tools

- Implementation times should decrease in order to raise competitiveness
- Should optimize the warehouse layout
- Helps make adjustments to the warehouse quicker
- Collaborators should not be exposed to labour intensive task, and solutions must increase in ergonomic conditions.
- Reduction of critical mistakes and oversights during the planning phase. Eliminate the human errors.
- Reliable transport of material to the assembly line
- Integration and communication between the system throughout the logistic process
- All data collected and/or processed must remain stored at local premises

4.3 Pilot specification

This section details the technical specifications required in order to realize the solution for trial 3. The section is organized in three sub-sections:

- **Legacy systems**

This sub-section provides an overview of existing data sources in the factory such as databases, sensors, etc. These sources will provide the data for the solution that address the trial's business requirements.

- **Components and infrastructure**

This sub-section provides an overview of the components that make up the solution for trial 3.

- **System requirements**

This sub-section provides an overview of the features required to address the business requirements of trial 3.

- **Design decisions**

This sub-section details design decisions that affect the development of the solution for trial 3.

4.3.1 Legacy Systems

The paragraph consists of a series of tables detailing the legacy systems involved in the solution for trial 3. The description includes relevant APIs, data formats, etc. along with details relevant to big data such as data volume, velocity etc.

Table 4-3 Manufacturing information and control system

Legacy system name			Fertigungs Informations und Steuerungssystem (FIS) Manufacturing information and control system
Type			Database
Details	*APIs*		Local access; VPN access;
	Data	*Description*	ıtrols vehicle production of the plant ordingly with the clients order bank.
		Format	.xlsx
Big Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralized on one database. Overall governance by VWAG, internal governance (plant) by contracted IT service provider
	Volume (size)		70 kB average per day (only data set for batteries)
	Velocity (e.g. real time)		High, real time, data entries
	Variety (multiple datasets, mashup)		Multiple datasets from different antennas of the main production sections
	Variability (rate of change)		High
Other Big Data Science (collection, curation, analysis, action - if applicable)	*Veracity (Robustness Issues, semantics)*		Low
	Visualization		VPN
	Data Analytics		N.A.

Table 4-4 LINCS Sequencing control system

Legacy system name			LINCS Sequencing control system
Type			Database
Details	*APIs*		Local access; VPN access;
	Data	*Description*	Manages and controls the picking lists for each sequencing area in the assembly line.
		Format	.xlsx
	Data Source		Centralized on one database with multiple tables.

Big Data Characteristics (if applicable)	*(distributed/centralized)*	Overall governance by contracted IT service provider (plant).
	Volume (size)	1.900 kB maximum per day (only data set for batteries)
	Velocity (e.g. real time)	Real-time
	Variety (multiple datasets, mashup)	Multiple datasets from the different tablet PC's in each sequencing area.
	Variability (rate of change)	High
Other Big Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*	Low
	Visualization	VPN
	Data Analytics	N.A.

4.3.2 Components and infrastructure

The paragraph consists of a series of tables detailing the components in the solution for trial 4. The description covers functionalities, data input/output, data formats, and integration needs of the components.

Table 4-5 UNINOVA Big Data Infrastructure

ID			BC-UNINOVA-1
Responsible partner			UNINOVA
Tool name			UNINOVA Big Data Infrastructure
Overall Description			UNINOVA developed a Big Data software infrastructure on top of Docker, for easy choice, configuration and setup of several Big Data tools, such as Apache Hadoop, Flink, Spark, Hive, Mahout, etc…
Details	*Functionalities offered*		4. Data analysis; 5. Data Management; 6. Analytics; 7. Storage & Querying
	Data input	*Description*	• All
		Format	Any (NoSQL, SQL, HDFS, Files, etc.).
	Data Output	*Description*	• All
		Format	Any (NoSQL, SQL, HDFS, Files, etc.).

	Integration requirements	N.A.
	BDVA mapping	If applicable indicate BDVA model mapping: 1. Data processing 9. Data Analytics 10. Data Management

Table 4-6 Easybot

ID			BC-ASTI-2
Responsible partner			ASTI
Tool name			Easybot
Overall Description			The **Easybot** is the best sold AGV in the ASTI's platform of AGVS.
Details	*Functionalities offered*		1. Follow a track on the floor defined by a magnetic tape 2. Execute actions according RIFD tag reading 3. Control based on commercial PLC 4. Circuit configuration can be done by the customer 5. Speed: 18 m/min – 40 m/min 6. Payload: 350 Kg 7. Towing capacity: 250N 8. Turning radius: 850 mm
	Data input	*Description*	• All
		Format	Sensors.
	Data Output	*Description*	• All
		Format	PLC Board
	Integration requirements		N.A.
	BDVA mapping		N.A.

Table 4-7 Mouseworld Laboratory

ID	BC-TELEFONICA-3
Responsible partner	TELEFONICA
Tool name	MOUSEWORLD LABORATORY
Overall Description	Telefonica counts with a Machine Learning Laboratory, called Mouseworld, which deals with network data analytics to early detect network related impairments. The objective in Boost4.0 is to

			apply it to the communication processes between the AGVs and the centralized control platform, to reduce the impact of such impairments in the AGVs behaviour.
Details	*Functionalities offered*		1. Synthetic data generation and AGV interactions replay 2. Network data collection & analytics 3. Machine Learning training and validation framework
	Data input	*Description*	• Network measurements from probes • Network logs • AGVs internal parameters
		Format	Netflow v9, CSV files, log files
	Data Output	*Description*	• Commands for AGV
		Format	PLC Board commands
	Integration requirements		The recommended actions for AGVs, determined by the Machine Learning algorithms, need to be integrated with the PLC that controls the AGVs behaviour.
	BDVA mapping		N.A.

Table 4-8 5TONIC Laboratory

ID			BC-TELEFONICA-4
Responsible partner			TELEFONICA
Tool name			5TONIC LABORATORY
Overall Description			5TONIC is a laboratory where experiments over the newest 5G technologies can be executed. Telefonica, as founding member, will provide the possibility to benchmark 5G as an improved communications channel for the AGVs.
Details	*Functionalities offered*		1. Testing over 4.xG and 5G technologies 2. Capability to emulate network impairments
	Data input	*Description*	• As required by the different experiments
		Format	TBD
	Data Output	*Description*	• As required by the different experiments
		Format	TBD
	Integration requirements		N.A.
	BDVA mapping		N.A.

4.3.3 System requirements

The paragraph consists of a series of tables detailing the software requirements in terms of features addressing the business needs of trial 4. The details include, associated business requirements, an overview of the functionality, data input/output, relevant

software requirements of the feature, interfaces, performance and other non-functional requirements.

Table 4-9 Software Requirement SR-WP5-VWAE-1

ID		SR-WP5-VWAE-1
Business requirement reference		Business Requirements: All Technical Requirements: All
Overall Description		**Big Data Extract-Transform-Load (ETL) Service:** The Big Data Extract-Transform-Load (ETL) Service deals with all the data related operations required to use the data in the Analytics or the Digital Twin Services.
Feature	*Introduction & Purpose of feature*	This service is responsible for handling data coming from heterogeneous data sources, both from pilot or third-party providers. Cleaning and harmonization processes will be implemented in order to ensure Data Veracity and Quality, before or after storing it into appropriate data storages, capable of loading and providing large volumes of data.
	Stimulus Response Sequence	Input: Legacy systems within VWAE, other relevant data sources; Output: Harmonized, cleaned, integrated data
	Functional Requirements	1. Extracts large volumes of data from heterogeneous sources; 2. Harmonizes, cleans and integrates large varieties of data, before and after storage; 3. Stores large volumes of ready-to-use data, in order to be sent to Big Data processing and Analytics services or to the Digital Twin Simulation services
External Interface Requirements	*User Interfaces*	Web Services and other Data adaptors
	Hardware Interfaces	N.A.
	Software Interfaces	Big Data Collectors and Processors (Apache Flume, Sqoop, Kafka, Spark) Big Data Processing engines (Apache Spark) Big Data Storage (HDFS, MongoDb, HBase)
	Communications Interfaces	N.A.
Performance Requirements		3. Able to handle large volumes of data (in the order of TBs); 4. Able to load, transform and unload large volumes of data fast when compared with traditional approaches (in the order of minutes or hours, instead of days);
Other non-functional requirements		Scalability, Reliability, Recoverability, Modularity, Distributed

Table 4-10 Software Requirement SR-WP5-VWAE-2

ID	SR-WP5-VWAE-2

Business requirement reference		Business Requirements: All Technical Requirements: T1, T2, T3, T4, T6, T8
Overall Description		**Big Data Processing & Analytics Service:** Big Data Processing & Analytics Service performs all the operations over the available data in order to obtain meaningful and useful information from it.
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 (Apache Spark MLLib), other algorithms may be added via DSL (Apache Mahout).
	Stimulus Response Sequence	Input: Harmonized, cleaned, integrated data; Data resulting from Digital Twin simulation Output: Insight data and knowledge in the form of Machine Learning, Data Mining and Analytics processes' results
	Functional Requirements	1. Implements Big data Processing engines in order to process large volumes of data already prepared and stored by the Big Data ETL service; 2. Integrates Machine Learning, Data Mining and Data Analytics algorithms with the Big Data Processing engines, in order to get insights on processed data;
External Interface Requirements	*User Interfaces*	Web Services and other Data Adaptors
	Hardware Interfaces	N.A.
	Software Interfaces	Big Data Processing engines (Apache Spark) Big Data Analytics tools (Apache Spark MLLib & Mahout)
	Communications Interfaces	N.A.
Performance Requirements		1. Able to handle large volumes of data (in the order of TBs); 2. Able to process and perform Data Analytics tasks over large volumes of data fast when compared with traditional approaches (in the order of minutes or hours, instead of days);
Other non-functional requirements		Scalability, Reliability, Recoverability, Modularity, Distributed, Data privacy

Table 4-11 Software Requirement SR-WP5-VWAE-3

ID	SR-WP5-VWAE-3
Business requirement reference	Business Requirements: All Technical Requirements: T1, T2, T3, T4, T6, T8
Overall Description	Big Data Visualization & Querying Services: • Integrates Big Data Visualization tools in order to study and analyse the data; • Enables efficient SQL queries on Big Data coming both from Big Data Extract-Transform-Load (ETL) and Big Data Processing & Analytics services

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 Big Data ETL and Processing & Analytics services; 2. Enables efficient SQL queries on Big Data coming both from Big Data Extract-Transform-Load (ETL) and Big Data Processing & Analytics services
External Interface Requirements	*User Interfaces*	Data Visualization and Querying user interfaces (Web-based)
	Hardware Interfaces	N.A.
	Software Interfaces	Big Data Visualization tools (Apache Zeppelin) Big Data Querying tools (Apache Hive, Apache Drill)
	Communications Interfaces	N.A.
Performance Requirements		• Able to handle large volumes of data (in the order of TBs); • 2. Able to process and perform Data Visualization & Querying tasks over large volumes of data fast, when compared with traditional approaches (in the order of minutes or hours, instead of days);
Other non-functional requirements		Scalability, Reliability, Modularity, Distributed, User-friendliness

Table 4-12 Software Requirement SR-WP5-VWAE-4

ID		SR-WP5-VWAE-4
Business requirement reference		Business Requirements: All Technical Requirements: All
Overall Description		**Digital Twin Simulation service:** • Simulates the AS-IS scenario of the VWAE Logistics processes (Four business processes) in order to: o Analyse and reduce critical mistakes; o Analyse and speed up implementation; o Increase process flexibility and efficiency; • Enables the modification/upgrade of the AS-IS scenario in order to: o Analyse and decrease design time for smarter solutions; o Improve ergonomics and reduce human dependency;
Feature	*Introduction & Purpose of feature*	This service is responsible for creating a present and future-driven Digital Twin, through a complete and accurate-to-reality simulation environment, in order to not only simulate the logistics processes as they exist today, but also to

		virtually analyse future modifications and their impact, both in terms of the processes themselves and the economic reliability of such modifications.
	Stimulus Response Sequence	Input: All data produced and gathered by previous services Output: Very close-to-reality simulation/Digital Twin
	Functional Requirements	1. Simulates the AS-IS scenario of the VWAE Logistics processes (Four business processes) in order to: • Analyse and reduce critical mistakes; • Analyse and speed up implementation; • Increase process flexibility and efficiency; 2. Enables the modification/upgrade of the AS-IS scenario in order to: • Analyse and decrease design time for 'smarter solutions; • Improve ergonomics and reduce human dependency;
External Interface Requirements	*User Interfaces*	Visual Components User Interface
	Hardware Interfaces	N.A.
	Software Interfaces	Visual Components Simulation Environment
	Communications Interfaces	AGV interfaces (4G, 5G, Wi-Fi), other interfaces (sensors, machines, etc.)
Performance Requirements		N.A.
Other non-functional requirements		N.A.

4.3.4 Design decisions

This section consists of two tables containing the design decisions that affects the development of the solution and a mapping of components and requirements in trail 3.

Table 4-13 Design decisions in trial 3

ID	Description	Justification	Relevant system requirements
1	Use Big Data collection tools for collecting data	Since the system will handle large volumes of data, specific Big Data collection tools, such as Apache Sqoop, Flume and Kafka, will be used to tackle the Data Volume and Velocity barriers when collecting structured and unstructured data from heterogeneous sources	SR-WP5-VWAE-1

2	Use Big Data Processing engines to perform initial cleaning, harmonization transformation of data, and processing tasks	Since the system will handle large volumes of data, specific Big Data Processing engines, such as Apache Spark, will be used to tackle the Data Volume, Velocity and Veracity barriers when performing cleaning, harmonization and transformation of data	SR-WP5-VWAE-1, SR-WP5-VWAE-2
3	Use Big Data Storage tools for storing data	Since the system will handle large volumes of data, specific Big Data Storage tools, such as Apache HDFS, Apache HBase and MongoDb, will be used to tackle the Data Volume and Velocity barriers when storing and retrieving data	SR-WP5-VWAE-1
4	Integrate ML, Data Analytics and Mining algorithms with Big data processing engines	Since the system will handle large volumes of data, specific Big Data Analytics tools which couple with already existing Big Data processing engines, such as Apache Spark MLLib and Apache Mahout, will be used to tackle the Data Volume, Velocity and Value barriers when processing and analysing the data	SR-WP5-VWAE-2
5	Integrate Big Data Visualization and Querying tools for better data understanding and analysis	Big Data Visualization and Querying tools, such as Apache Zeppelin, Apache Hive and Apache Drill, will be used to tackle the Data Volume, Velocity and Value barriers when users need to interact with such large volumes of data	SR-WP5-VWAE-3
6	Perform Network Data Analytics and direct testing over 5G technologies to tackle the problem of network noise inside VWAE shop floor and logistics areas	Since there is a specific concern about future implementations and improvements due to networks' noise inside the factory, specific Big Data processing and analytics will be performed over network data inside the factory. In addition, testing over real equipment will be done in 5TONIC with the aim of comparing both Wi-Fi and 5G performances.	SR-WP5-VWAE-1, SR-WP5-VWAE-2, SR-WP5-VWAE-3

7	Build a very close to reality simulation as a Digital Twin	Simulate the AS-IS scenario of the VWAE Logistics processes (Four business processes) in order to: . Analyse and reduce critical mistakes; . Analyse and speed up implementation; . Increase process flexibility and efficiency; Enable the modification/ upgrade of the AS-IS scenario simulation in order to: . Analyse and decrease design time for smarter solutions; . Improve ergonomics and reduce human dependency;	SR-WP5-VWAE-4
8	Use AGVs to gather data for future improvements on transportation and network management inside VWAE logistics area	AGVs from ASTI will be used to test the future scenarios for reducing human dependency, while providing useful insights on how to connect smarter solutions within the factory. It will also provide transportation data	SR-WP5-VWAE-1, SR-WP5-VWAE-4

Table 4-14 Components used in trail 3

Component ID	Component Name	System Requirement References	Comments
1	UNINOVA Big Data infrastructure	SR-WP5-VWAE-1, SR-WP5-VWAE-2, SR-WP5-VWAE-3	N.A.
2	Visual Components Simulation Environment	SR-WP5-VWAE-4	N.A.
3	5G 5TONIC Lab and TID Network	SR-WP5-VWAE-1, SR-WP5-VWAE-2,	The 5Tonic framework will address the particular problem of connectivity noise inside the

	Analytics Mouseworld Lab	**SR-WP5-VWAE-3**	shop floor, that impacts in AGVs operation, by collecting data and evaluating it over the Mouseworld lab.
	ASTI Easybot AGVs	**SR-WP5-VWAE-1, SR-WP5-VWAE-4**	AGVs from ASTI will be used to test the future scenarios for reducing human dependency, while providing useful insights on how to connect smarter solutions within the factory. It will also provide transportation data

5 Trial 4: +GF+

The section consists of two main parts and provides details for trial 4:

1. **Pilot overview**

Provides explanations about the manufacturing processes and plants involved in the trial. Additionally, it explains the objectives to be achieved and the partners involved.

2. **Business requirements**

This section provides an overview of the business processes involved in the trial.

3. **Pilot specification**

Details the technical specifications required in order to realize the solution for each trial. This includes descriptions of legacy systems to be integrated, software components, and software requirements.

5.1 Pilot overview

5.1.1 General description

The trial and target factory is described in Figure 6. The main features of the GF pilot are categorised across 3 main streams, anomalies detection and visualisation at the level of component manufacturing with GF machines, the predictive maintenance system which is intertwined with the component or part dimensional measurement, and the part localisation and traceability during the assembly process.

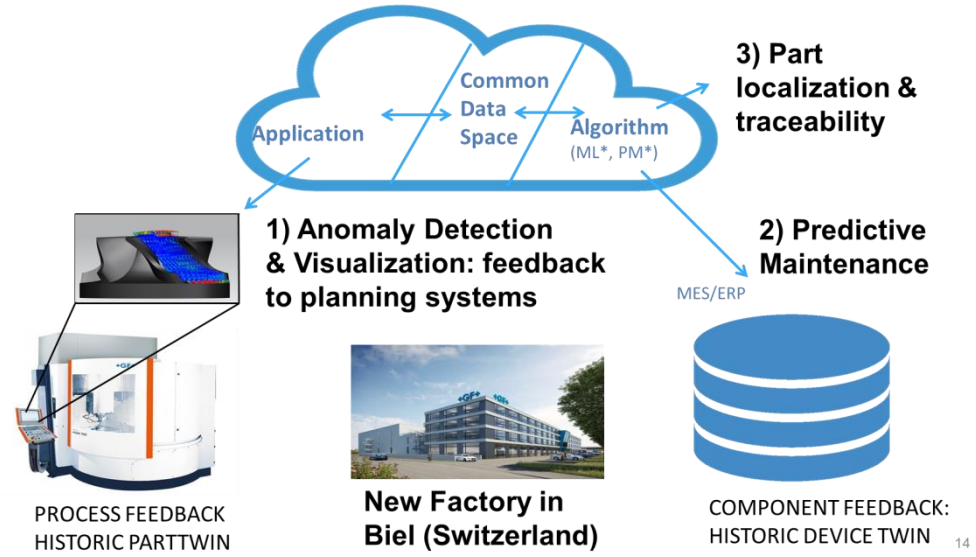

Figure 6 Trial 4 overview

The target site will be the new GF factory in Bienne, Switzerland, where milling, laser, and advanced manufacturing systems will be produced as of 2019. In particular the critical stage of the manufacturing of spindles will be a focus as it contains an automated system using GF milling machines, so these machines will be monitored together with the parts they produce in order to control and improve quality and productivity before assembly. The assembly line will be the second focus and will help to demonstrate the benefits of a fully digitised and real time-controlled system targeting maximum productivity and quality of assembly. A connectivity system will finally allow to recover in the common data space the data from machines in the field.

Table 5-1 Trial 4 application domains

Application Domain*		Description and justification of the application domain
Smart Digital Engineering	X	*Integration of operations feedback to engineering knowledge base*
Smart Production Planning & Management	X	*Smart, cognitive planning system for the manufacturing of milling machines*
Smart Operations & Digital Workplace	X	*Fully digitised assembly processes*
Smart Connected Production	X	*Industrial Data Space*
Smart Maintenance & Service	X	*Predictive maintenance across full lifecycle*

5.1.2 Objectives

The main objectives and benefits of the GF pilot are the following:

Improve machine assembly lead time and quality towards zero-defect, with cost optimization

Development of a Digital supply chain and smart assembly: Implement real time traceability of critical supplies and digitalisation of assembly process information, integrated into an agile planning system with common databases and standards, for real time assessment of operations and just-in-time management of supplies in coordination with suppliers through digital, cloud-based ERP bridges.

Optimization of production planning based on predictive models for manufacturing assets, quality controls and supply requirements.

Development of Machine Product and part digital twins: Assembled products are traceable and virtualised in the common core space which is associated with the information describing their manufacturing history, including the dimensional measurements, and the performances of manufacturing processes made by each machine, from the component production at GF operations until the stage where the device operates at the customer factory, in order to predict and anticipate failures, parts defects and provide feedback to assembly and engineering planning

Zero defect control through Digital, cognitive lean manufacturing.

Develop and demonstrate a decentralised cognitive management system for zero defect manufacturing: Providing access to information across the value chain and beyond through a common data space which will be available to every stage of operations and to GF and customer management through seamless dashboards. Cognitive systems are spread through planning, execution, traceability and monitoring applications which operate in coordination.

5.1.3 Participants

You can find an extended description for each of the participant in APPENDIX 1: Participant description

Table 5-2 Trial 4 participants

+GF+	+GF+ Leading manufacturer of Machine Tools for different technologies, offering also automation system and associated software.	Main partner of the pilot
EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE	ECOLE POLYTECNIQUE FEDERALE DE LAUSANNE One of the two Swiss Institute of Technology, educating more than 10,000 students in all engineering disciplines	Will be responsible for the Development of Big Industrial Data Analytics solutions and predictive models.
esi get it right®	ESI GROUP Leading innovator in virtual prototyping software and services	Will provide with the ICT solution for the big data analytics and simulation in the pilot

5.2 Business requirements

This section specifies the business requirements that the solution that will be implemented in this pilot must meet:

- Provide real time information to operators and central smart planning system
- Predictive maintenance system coupled with the quality control should improve the maintenance process and reduce/eliminate defected parts
- Maintenance should be operated only when needed
- Create an interactive digital assemble tool, easily used by operators.
- Feed the central smart planning system
- Make visible the KPIs and combine information to pursue zero-defect manufacturing
- Datasets should be standardized
- ML should be trained on appropriate datasets
- Monitoring should be realized in real-time
- Dashboard applications should be accessible to every involved actor

5.3 Pilot specification

This section details the technical specifications required in order to realize the solution for trial 4. The section is organized in three sub-sections:

- **Legacy systems**

This sub-section provides an overview of existing data sources in the factory such as databases, sensors, etc. These sources will provide the data for the solution that address the trial's business requirements.

- **Components and infrastructure**

This sub-section provides an overview of the components that make up the solution for trial 4.

- **System requirements**

This sub-section provides an overview of the features required to address the business requirements of trial 4.

- **Design decisions**

This sub-section details design decisions that affect the development of the solution for trial 4.

5.3.1 Legacy Systems

The paragraph consists of a series of tables detailing the legacy systems involved in the solution for trial 4. The description includes relevant APIs, data formats, etc. along with details relevant to big data such as data volume, velocity etc.

Table 5-3 Siemens/Heidenhain

Legacy system name			Siemens/Heidenhain
Type			Milling, Turning, Grinding
Details	*APIs*		
	Data	*Description*	Process data form machine
		Format	Csv file
Big Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralized
	Volume (size)		+/- 5MB per hour of machining (as csv)
	Velocity (e. g. real time)		0.5 seconds sampling rate
	Variety (multiple datasets, mashup)		• Sensor from machine: Time, Program, Line number, Tool, Spindle (speed, load, vibration), Feedrate (incl. override), Axis (position, load), Temperature (env, spindle, motor), and Coolant conditions
	Variability (rate of change)		-
Other Big Data Science (collection, curation, analysis, action - if applicable)	*Veracity (Robustness Issues, semantics)*		-
	Visualization		-
	Data Analytics		Early failure detection (for maintenance)

Table 5-4 Power Inspect / Calypso

Legacy system name			Power Inspect / Calypso
Type			CMM machine
Details	*APIs*		Native from software
	Data	*Description*	Measurements data

		Format	Pdf, txt
Big Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralized
	Volume (size)		~0
	Velocity (e. g. real time)		NA
	Variety (multiple datasets, mashup)		• X,Y, Z in one physical point • X,Y, Z in one theoretical point • Deviation along measurement direction
	Variability (rate of change)		-
Other Big Data Science (collection, curation, analysis, action - if applicable)	*Veracity (Robustness Issues, semantics)*		-
	Visualization		-
	Data Analytics		Projects done: • MPP : multi-process planning • TRUE: automated cell including CMM measurements for high precision

Table 5-5 LLQA

Legacy system name			LLQA
Type			Assembly operating system
Details	*APIs*		
	Data	*Description*	Assembly instructions (Assembly operations feedback)
		Format	Csv file
Big Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralized
	Volume (size)		+/- 0.1 MB per hour of operations (as csv)

	Velocity (e. g. real time)	1 hr sampling rate
	Variety (multiple datasets, mashup)	Assembly operations feedback: Time, Components, Tool, Tolerances, Checklists, Temperature, and Environment conditions
	Variability (rate of change)	-
Other Big Data Science (collection, curation, analysis, action - if applicable)	*Veracity (Robustness Issues, semantics)*	Natural language for remarks
	Visualization	-
	Data Analytics	-

5.3.2 Components and infrastructure

The paragraph consists of a series of tables detailing the components in the solution for trial 4. The description covers functionalities, data input/output, data formats, and integration needs of the components.

5.3.2.1 +GF+ domain ontology

Table 5-6 +GF+ domain ontology

ID	BC-EPFL-1
Responsible partner	EPFL
Tool name	+GF+ domain ontology
Overall Description	The main approach of the +GF+ Pilot is based upon exploitation of various data sources (Component, machine, production, quality, product and business data) and access to different aspects of machinery and process related to data and knowledge. Its innovation lies on the incorporation of various domains of knowledge in the way of semantic knowledge representation formalisms. In the main architecture, the GFMS Pilot semantic model plays the role of the backbone of the entire platform in the middleware, and will be implemented by EPFL in the form of an ontology. The ontology, as a common reference model, provides the capability of integration of heterogeneous data. Establishing a methodological framework, the GFMS Pilot ontology delivers the meta-model describing not

	only the actors and procedures at the shop floor, but also machinery and their critical components, their failure modes and their criticality, their signature of healthy and deteriorated conditions, and ensures full interoperability not only within different data sources but also with the other BOOST 4.0 modules. In addition, it facilitates semantic enrichment (e. g. annotations, tagging) that can be used for assessing the capabilities of the BOOST 4.0 analytics framework across the production life-cycle, active exploration of the linked data sets, and implicit knowledge discovery.		
Details	*Functionalities offered*		• Data schema • Reference model for data flow • Inference and reasoning
	Data input	*Description*	Since +GF+ domain ontology is a reference model, there is no data input or output.
		Format	
	Data Output	*Description*	
		Format	
	Integration requirements		BOOST 4.0 Industrial Data Space & Infrastructure
	BDVA mapping		• Data Management • Development – Engineering and DevOps

5.3.2.2 Scilab

ID	BC-ESI-2		
Responsible partner	ESI		
Tool name	Scilab		
Overall Description	Scilab is free and open source software for numerical computation providing powerful computing environment for engineering and scientific applications.		
Details	*Functionalities offered*		1. Maths & Simulation 2. 2D & 3D Visualization 3. Optimization 4. Machine learning & Statistics 5. Control System Design 6. Signal & Image processing 7. Xcos – Hybrid dynamic systems modeler and simulator
	Data input	*Description*	• Simulation data • Financial data • Process data

			• Experimental data
		Format	Ascii, csv, xls, .mat, xml
	Data Output	*Description*	Pre- or Post-processed data
		Format	Ascii, csv, xls, .mat, xml
	Integration requirements		Available on Windows Vista, 7, 8, 10, GNU/Linux & Mac OS X
	BDVA mapping		-

5.3.3 System requirements

The paragraph consists of a series of tables detailing the software requirements in terms of features addressing the business needs of trial 4. The details include, associated business requirements, an overview of the functionality, data input/output, relevant software requirements of the feature, interfaces, performance and other non-functional requirements.

Table 5-7 Software requirement SR-WP5-T5.1-1

ID	SR-WP5-T5.1-1	
Business requirement reference	Help the data scientist to design relevant prediction models for the spindle component manufacturing	
Overall Description	Data analysis for smart training that will be handled by INENDI Inspector.	
Feature	*Introduction & Purpose of feature*	The goal of this feature is to help the data scientist to: - Navigate through the overall data sets generated during the spindle component manufacturing and the spindle components quality inspection - Extract relevant subsets of the overall gathered data to make training data sets for building prediction models. - Evaluate the efficiency of the predicted model
	Stimulus Response Sequence	In - Data gathered from +GF+ machines: for a regular check of the efficiency of the prediction model Out - Subset of smart data to update the prediction model
	Functional Requirements	• System shall import machines data • System shall visualize the data and help the data scientist to find most relevant one for further machine learning training • System shall finally store the smart subset of data within the data management system • System shall help the data scientist to check the efficiency of the predicted model built.
	User Interfaces	**Analysis** INENDI Inspector front end which is an interactive visualization software for Big Data. **End user**

External Interface Requirements		The tool will not be accessible to the operator. But it must be accessible to data scientist/analyst/manager, and could be accessible to production engineer/manager.
	Hardware Interfaces	None
	Software Interfaces	None
	Communications Interfaces	Interface with the data base
Performance Requirements		• Must be able to load different data sources (machining data and quality data) and navigate between them.
Other non-functional requirements		None

Table 5-8 Software requirement SR-WP5-T5.2.2-1

ID		SR-WP5-T5.2.2-1
Business requirement reference		Smart workshop production planning
Overall Description		Machine learning algorithm for predictive maintenance (EPFL ontology)
Feature	*Introduction & Purpose of feature*	The goal of this feature is to be able to model failure occurrence in order to prevent it at the right moment
	Stimulus Response Sequence	**Training phase** In - Smart set of data Out - Model **Production phase** In - Process data Out - Decision indicator
	Functional Requirements	• System shall train a machine learning model on a given data set • System shall then provide relevant indicators regarding machine maintenance
External Interface Requirements	*User Interfaces*	**Designer** Could be access through the platform where the model is deployed (may be Scilab) **End user** The tool will not be accessible to the end user
	Hardware Interfaces	None
	Software Interfaces	None

	Communications Interfaces	Interface with the data base
Performance Requirements		"Real-time" prediction
Other non-functional requirements		None

Table 5-9 Software requirement SR-WP5-T5.3.2-1

ID		SR-WP5-T5.3.2-1
Business requirement reference		Smart workshop production monitoring
Overall Description		KPIs visualization and overall monitoring thanks to EPFL or Scilab solutions
Feature	*Introduction & Purpose of feature*	The goal of this feature is to provide the end user with relevant KPIs accessible via a visualization tool which will allow fast and efficient monitoring of the overall workshop production.
	Stimulus Response Sequence	In – Data, mainly KPIs and predictive maintenance results Out - Graphics
	Functional Requirements	• System shall import data from the data management system • System shall display relevant graphics and figures for workshop production monitoring
External Interface Requirements	*User Interfaces*	**End user** One graphical user interface that might be customizable
	Hardware Interfaces	None
	Software Interfaces	None
	Communications Interfaces	• With the data base • With GF SAP suite (to be discussed)
Performance Requirements		Depending on GF needs, this system should be able to display data in "real-time". Could be minutes, hours or day (to be discussed).
Other non-functional requirements		None

Table 5-10 Software requirement SR-WP5-T5.3.2-2

ID	SR-WP5-T5.3.2-2

Business requirement reference	Smart workshop production planning	
Overall Description	Planning application for optimal workshop production operation based on Scilab	
Feature	*Introduction & Purpose of feature*	The goal of this feature is to provide the end user with the ability to make smart planning all along his workshop production, taking into account gathered and computed data such as operation KPIs and predictive maintenance results.
	Stimulus Response Sequence	In - KPIs and predictive maintenance data Out - Optimized planning from supply chain to final assembly
	Functional Requirements	• System shall be able to import data from the data base • System shall be able to run EPFL predictive maintenance algorithms (if no more efficient way) • System shall be able to optimize the workshop production plan based on data
External Interface Requirements	*User Interfaces*	**Developer** The optimization and EPFL algorithms can be accessed through the Scilab integrated development environment **End user** The end user will access the whole feature through a dedicated graphical interface.
	Hardware Interfaces	None
	Software Interfaces	None
	Communications Interfaces	Interface with GF SAP suite in order to integrate the tools developed within Boost4.0
Performance Requirements		Depending on GF needs, this system should be able to operate in "real-time". Could be minutes, hours or day (to be discussed).
Other non-functional requirements		None

5.3.4 Design decisions

Table 5-11 Design decisions in trial 4

ID	Description	Justification	Relevant system requirements
LLQA V2	Assembly line interactive operational system	Obtaining data from assembly processes	Interactive interface, Windows OS

6 Trial 5: FIAT autonomous assembly line factory 4.0

6.1 Pilot overview

The section consists of two main parts and provides details for trial 6:

- **Pilot overview**

Provides explanations about the manufacturing processes and plants involved in the trial. Additionally, it explains the objectives to be achieved and the partners involved.

- **Business requirements**

This section provides an overview of the business processes involved in the trial.

- **Pilot specification**

Details the technical specifications required in order to realize the solution for each trial. This includes descriptions of legacy systems to be integrated, software components, and software requirements.

6.1.1 General description

The general objective of the trial is to support the automation and itemization of Automotive industrial processes. These processes are enabled by autonomous production cells replenished and connected by Automated Guided Vehicles (AGVs), as in the figure below (Figure 6-1).

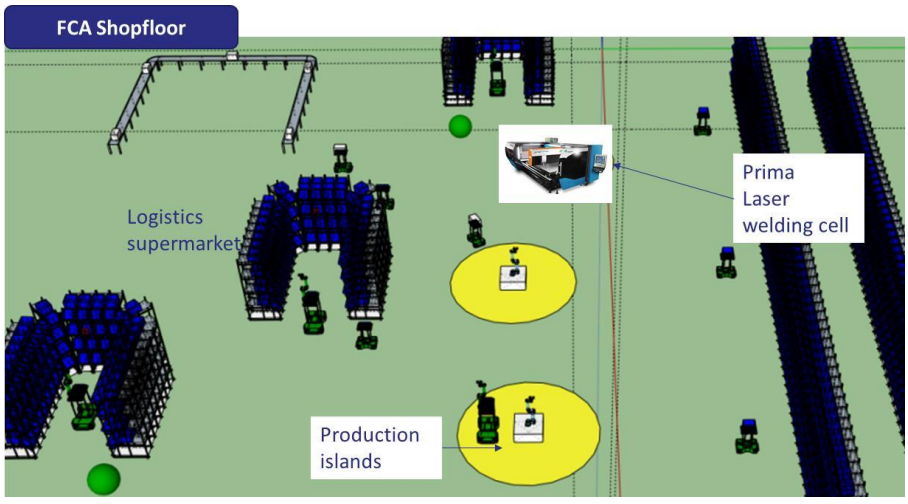

Figure 6-1 FCA Shop Floor Schema

In detail, the trial will demonstrate:

- The evaluation of incoming event (delay, failure) in the productive process
- The predictive maintenance of the AGVs
- The predictive maintenance of the laser cell (Prima)

The trial will be held in the Campus Melfi, a small-scale plant for small-lot production. It will use MindSphere as connectivity and implementation platform: predictive maintenance algorithms will be developed into a specific application running on MindSphere (MindApp).

The actual reference architecture (AS IS) starts from the field (AGVs and Prima Laser Machine). Each device is connected to a supervising system (typically a SCADA or a supervising Workstation) for core automation functionalities. If data are used at IT level (i.e. by an ERP system), then a Manufacturing Execution System is used as a bridge between the core automation (OT) and the information systems (IT). The architecture is detailed in Figure 6-2.

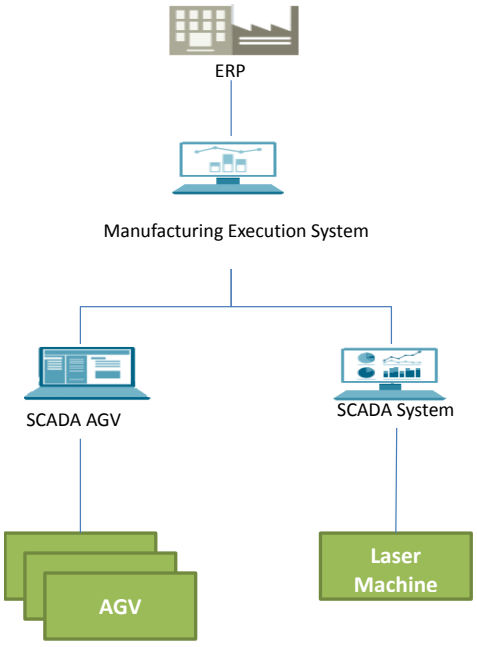

Figure 6-2 System Architecture

Table 6-1 Trial 5 application domains

Application Domain*		Description and justification of the application domain
Smart Operations & Digital Workplace	X	Set-up of technical validation, large scale experimentation & on-site trials. Perform rapid prototyping and early assessment of BOOST 4.0 data pipeline and tools on business impact Instantiate and optimize BOOST 4.0 framework deployment in large scale and in-situ pilots for advanced big data-driven autonomous assembly line. Consolidate and generalize particular pilot findings into the general BOOST 4.0 impact evaluation framework.

6.1.2 Objectives

FIAT autonomous assembly line factory 4.0 aims to provide the maximum flexibility to potential changes in the demand or to issues/delays/changes in the logistics or productive systems by means of using available and new datasets (such as flows of components in the plants and their precise localization) ensuring business continuity, at the same time the over-dimensioned fleet of robots is reduced and the (big-) data are shared among the whole value chain (providers, maintenance services etc.).

In autonomous production, the traditional linear process is removed and Mobile Robots enable a higher level of autonomy, re-configurability and robustness to external events. The control of the AGV fleets, their availability and reliability to respect cycle time and leadtime is crucial to ensure the stability and throughput of the production systems.

The main objectives of the trial are to ensure that the new technology will be robust enough to avoid business interruption (e. g. stock-out, unwanted waiting or idle time for the machine), delays and reduction of throughput.

The general benefits expected are to:

- Reduce the overall maintenance costs
- Increase the throughput
- Increase the availability of the production system
- Increase the saturation of material handling systems
- Decrease the cycle time

6.1.3 Participants

You can find an extended description for each of the participant in APPENDIX 1: Participant description

Table 6-2 Trial 5 partcipants

FCA FIAT CHRYSLER AUTOMOBILES	FIAT CHRYSLER AUTOMOBILES Designs, engineers, manufactures and sells vehicles and related parts and services through 159 manufacturing facilities, 87 R&D centres, and dealers and distributors in more than 140 countries.	Main partner of the pilot Will host the trial in the Campus Melfi.
PRIMA INDUSTRIE	PRIMA INDUSTRIE Is a worldwide leader in the field of industrial laser system and sheet metal working machines. The core of the technology Innovation for Prima is represented by three main topics: laser and photonics, Industry 4.0 and advanced manufacturing processes.	Will contribute by adapting the existing laser machines to the requirements of the pilot.
SIEMENS	SIEMENS MindSphere is the cloud-based, open IoT operating system that connects real things to the digital world, and enables powerful industry applications and digital services to drive business success. MindSphere's open Platform as a Service (PaaS) enables a rich partner ecosystem to develop and deliver new applications.	Will provide with an IoT Operation System, industrial know how and digitalization expertise.

6.2 Business requirements

- Inter connected laser machine
- AGV for pallet: customized clamping system integrated in the palled

- Instant rescheduling of the machine
- Quality control reporting timing must be reduced
- Forecasting maintenance operations and failures
- Role-based data access, and adapted user interface
- Possibility to develop predictive algorithms
- Graphic display for data and analysis results

6.3 Pilot specification

This section details the technical specifications required in order to realize the solution for trial 5. The section is organized in four sub-sections:

1. **Legacy systems**

   This sub-section provides an overview of existing data sources in the factory such as databases, sensors, etc. These sources will provide the data for the solution that address the trial's business requirements.

2. **Components and infrastructure**

   This sub-section provides an overview of the components that make up the solution for trial 5.

3. **System requirements**

   This sub-section provides an overview of the features required to address the business requirements of trial 5.

6.3.1 Legacy Systems

Two main legacy systems are part of the pilot:

- The sensing systems on board of the AGC and PRIMA cell. This are custom deployment of existing of-the-shelf systems, used in several plants and implemented in the Campus Melfi.
- The MES and WMS implemented in the plant. Also, in this case instances of the systems used in the FCA plants were customised to the Campus Melfi.

6.3.2 Components and infrastructure

Sensing systems will collect data coming from the shop-floor, both from the AGVs and PRIMA cell. As described above, these systems will not be modified during the pilot. Adequate protocols to transfer these data to the Cloud will be developed: data coming from the sensors and from the MES (Manufacturing Execution Systems) and WMS (Warehouse Management Systems) data, to be used to correlate sensor data with production planning and control data.

At EDGE level preliminary analysis enables to detect outliers, verify and prepare data. MindConnect Nano or other BOOST 4.0 adequate hardware and protocols, MindConnect libraries are used as integration layer towards the cloud.

Finally FIWARE tools for Data management, Data processing, Data visualisation and Data analytics (including Complex Event Processing) will be used. Using IDS connectors provide secure data exchange and enables communication within the ecosystem of the Industrial Data Space.

6.3.3 System requirements

On a high level view, functional requirements include:

- Interaction between AGV and cell in real-time
- Quality analysis in real-time
- Data acquisition for monitoring and diagnosis in near real-time
- Advanced visualisation of multi-parameter, multi-level data.

7 Trial 6: PHILIPS Autonomous short-batch injection moulding production process

The section consists of two main parts and provides details for trial 6:

- **Pilot overview**

Provides explanations about the manufacturing processes and plants involved in the trial. Additionally, it explains the objectives to be achieved and the partners involved.

- **Business requirements**

This section provides an overview of the business processes involved in the trial.

- **Pilot specification**

Details the technical specifications required in order to realize the solution for each trial. This includes descriptions of legacy systems to be integrated, software components, and software requirements.

7.1 Pilot overview

7.1.1 General description

The trial in the PCL case will take place in the Drachten mass-production manufacturing facility. Drachten is one of the key manufacturing sites for supplying the worldwide shaver market. The Drachten facility is vertically organized, meaning that the large majority of the products (shavers) are manufactured and assembled in-house (Figure 7-1).

Technical Expert Group
Innovation Domestic Appliances & Coffee
• Floor Care • Coffee • Air
Innovation Personal Care
• Male Grooming: Shaving and Grooming • Skin Care • Female Beauty: Female Depilation
Innovation Sleep and Respiratory Care
Healthy Sleep Solutions: Wake-up Lights and Energy Lights
Operations
• Industrialization and production of Philips Shavers and Philips OneBlade cutting elements

Figure 7-1 Philips Drachten organization

Next to the manufacturing of shavers (Operations), the site also contains multiple innovation departments as well as technical expert group. Philips Drachten currently employs about 2000 people. The focus for the pilot will be on the operation activities.

The Drachten manufacturing facilities contain about 1000 production units (PU's). The most important manufacturing processes are divided in:

- Cold forming and Hardening
- Metal finishing (Electrochemical, Spark erosion etc.)
- Plastic part making (Injection Moulding)
- Automated assembly (Robotics, Flexible automation)
- Part finishing (Painting, Lacquering)

Boost Focus area: Injection Moulding

Injection moulding is the process of shaping of rubber or plastic parts by injecting heated material into a mould

- The process itself is relatively standardized
- Used mostly for mass production
- Philips Drachten has approximately 90 injection moulding machines deployed

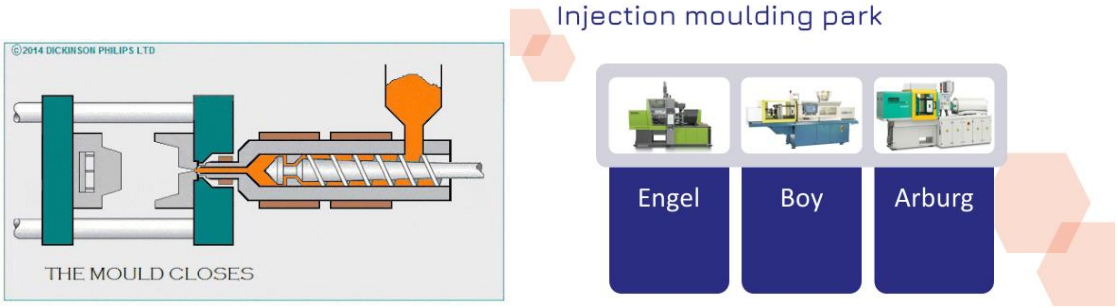

Figure 7-2 Process overview and different brands

Philips deploys many different types of machines and generations, from three main brands (Engel, Boy and Arburg).

From a process point-of-view, the three brands are quite similar. When looked into the communication structure, however, we find the following challenges:

- Each has different communication standards and protocols
  - CodeSys, OPC-DA (classic), OPC-UA, serial, Ethernet, Bandwidth etc.
- Each standard and protocol mean a different data structure
  - Language, tag-names, frequency of data, markup (Json, Xml, CSV etc.)

Our current data acquisition and analytic platform cannot cope with all these differences, meaning a dedicated solution per machine need to be developed. Of course, the amount of work required would be huge and would take many years. In order to achieve our goal, we need a generic data model and standardized platform.

Table 7-1 Trial 6 application domains

Application Domain*		Description and justification of the application domain
Smart Operations & Digital Workplace	X	The application domain is focused mainly on allowing smarter operations (manufacturing) and providing operations with a digital work environment to help them improve production KPI's, as well as provide them with additional insights to effectively solve and prediction production failures.

7.1.2 Objectives

7.1.2.1 Objective of the BOOST Trial

Philips Drachten encompasses a large suite of highly automated processes used during the manufacturing of electric shavers. Of these manufacturing processes, injection moulding is of particular importance, as this is used during the fabrication of plastic components for electric shavers. All of these plastic parts are manufactured onsite at Drachten, requiring approximately 80-90 moulding machines. Injection moulding, however, is a competitive market, making it essential for Philips Drachten to continuously improve on quality, production performance, and costs where this process is concerned.

Next to the aforementioned metrics, the application of Big Data along with seamless connectivity in the manufacturing process will result in efficient ramp-up times between different moulds, along with full traceability along the process chain all the way to the customer.

From a strategic standpoint, it is expected that the technologies developed in Boost 4.0 can be developed into new autonomous modes of manufacturing. Production customization will be made possible, implying frequent product changeover and smaller batch sizes. Innovative Big Data Cognitive Manufacturing Processes. This pilot will deploy a series of technologies that will facilitate increased quality and productivity.

7.1.2.2 Main challenges

The whole injection moulding park is connected to a dedicated machine network. This means that, to a certain extent, process data can be retrieved from each of these machines. One of the main challenges is to be able to generalize the data and structure across multiple models and brands of equipment.

Different models, generations, brands and types of machines all have different methods and structures for transmitting data. To give some examples; some older machines only connect via serial connection, some machines can only transmit data via file transfer and each manufacturer has his own internal data structure.

From a process engineering standpoint, injection moulding processes are well-described in literature and the basic moulding process should be comparable. As the moulding process is well-documented, we see opportunities to build generalized data analysis models describing the many features of the process and indicating (unwanted) trends, outliers and other sort of deviations. These models should be deployable across the majority of the machine park.

By combining a generalized data framework and combining it with generalized data models, we expect to:

1. Be able to better monitor product quality (predictive quality)
2. Be able to predict upcoming machine/part failures (predictive maintenance)
3. The ability to control machine parameters and trigger actions on the physical devices (control loop)

7.1.2.3 Objectives for the project

From a more specific point of view, the main objectives for the project are:

1) A new data collection and storage infrastructure will be deployed to effectively integration various types of data into a single common repository. This will include state-of-the-art technologies like streaming, edge computing and cloud computing.
2) Visualization of data: results of data monitoring and machine learning results must be made available to process engineers, assembly line operators, and data scientists. New dashboard/UI applications will be made available, as part of our big data infrastructure update.
3) Predictive maintenance: suitable machine learning algorithms will need to be applied to our datasets in order to give advance notice of anomalous behavior and/or tooling malfunctions.
4) Deep understanding of injection moulding processes: it is desired to compile a shortlist of the most significant features from the available data, which contains approximately 10k features per machine. A thorough exploration of our data will be undertaken in order to select out the most significant features related to our processes Outcome

7.1.2.4 Strategic goals and benefits

The strategic goals of PCL are to reduce Cost of Operations and Cost of non-Quality. The following four performance indicators are defined:

1) Predictive Quality – 10% improvement on Fall Off Rate (FOR)
   By using advanced analytics, we can model the injection moulding system and use this to monitor and understand quality output. Better control of our processes means less fall-off due to quality reasons and reduce the FOR.

2) Predictive Maintenance – 5% less down time (OEE-A)

   Similarly, to predictive quality, a model describing the injection moulding process will also be able to indicate behavior related to components on the machine. Blockage, temperature and current can indicate wear and/or impending failures.

The ability to detect these make them plannable and will decrease unexpected downtime.

3) Intelligent process control – Contributes to predictive quality (in process-control)

The ability for deploying analytic model on the (real-time) data streams allows for real-time processing. The output of the models can be connected to the PLC of the machine, to allow for a closed-loop control system based on machine learning algorithms. This will allow for even more improvements of the FOR.

4) Give operators better tools – Mean Time To Repair improvement of 5%

By using specialized algorithms on the aforementioned models, we can allow for automated root-cause analysis. Deviation in process behavior is linked to specified error causes. This allows for an advisory system which will dynamically generate advice for operators to help them troubleshoot production issues.

7.1.3 Participants

You can find an extended description for each of the participant in APPENDIX 1: Participant description

Table 7-2 Trial 6 partcipants

	PHILIPS CONSUMER LIFESTYLE develops numerous innovative products, such as shavers, beard trimmers, hairdryers, epilators, vacuum cleaners, SENSEO® coffee machines, and Wake-up Lights. Philips Drachten also develops and produces the shavers and parts for the global market.	Main partner of the pilot
	PHILIPS RESEARCH is a global organization that helps Philips introduce meaningful innovations that improve people's lives. We provide technology options for innovations in the area of health and well-being, targeted at both developed and emerging markets	The department builds on several interconnected competences including Machine Learning, statistics, probability models, pattern recognition, computer vision, signal processing and data engineering.

imec	IMEC Is the world-leading R&D and innovation hub in nanoelectronics and digital technologies.	As a trusted partner for companies, start-ups and academia we bring together brilliant minds from all over the world in a creative and stimulating environment.

7.2 Business requirements

This section specifies the business requirements that the solution that will be implemented in this pilot must meet:

- Platform should support all injections moulding brands and types
- Platform scalable to all machines
- Platform must be secure
- Platform should provide user-roles and access restriction
- The solution must fit within the Philips network structure
- Must be compatible with other systems used and support international standards
- The MIT/data engineers must be able to control and extend the platform
- No privacy related information (like name of operators) shall be stored without permission
- System is redundant for failures and supports external data sources
- No technical knowledge about protocols required to connect new machines. Create a step by step interface for guiding the user.
- Ability to connect to machine control directly
- Must support real-time data streams or historical data, and local or cloud data processing
- Data must be organized, clear, specific and understandable
- Each control action on machines needs to be logged
- Advanced control can be easily monitored remotely
- Visual indicator for automated control actions taken
- Dashboards can be accessed without training, and information will make sense
- Dashboards shall be web-based and mobile friendly
- Dashboard will be setup in a secure environment, not accessible outside Philips network
- Dashboard deployment must be easy, fast and with no specialized IT support required
- Dashboard design will be suitable for all injection moulding machines

7.3 Pilot specification

7.3.1 Legacy Systems

For the pilot, two main legacy systems are identified:

- The production equipment
- The production control platform (FIS)

More details in the about the existing legacy systems can be found in the following paragraphs.

7.3.1.1 Production equipment

Philips Drachten deploys injection moulding equipment from three main brands; ranging from older to newer generations.

Currently, about 93 machines are deployed, with ages of the equipment ranging from 1993 to 2018. Each machine has unique configurations related to the output product. There is a list of all equipment available, but this cannot be shared publicly.

7.3.1.2 The production control platform (FIS)

In the late '80s of last century, Philips decided to build its own manufacturing control process dedicated to Drachten' manufacturing processes. At a later stage, a copy was made and specified to Injection moulding management (this was called Amphora). Amphora is built on top of a number or Oracle databases, taking data from both individual machines, the Engel Production platform, the ERP system (SAP) and operators. Although a new MES system is currently introduced to production, it still heavily relies on Amphora.

7.3.2 Components and infrastructure

As the machines (BOY 19 / 20) are not capable of reporting via the OPC-UA standards (it's based on Codesys 2.3, which does not support OPC-UA) several translations are done on the factory network. The factory network is based on 'regular' Ethernet connections. All production machines are connected to this machine network. Firewalls and other security measures make sure the factory network is more or less fully disconnected from the office network.

Via a Kafka bus, we can retrieve data from the machine network and use it for local processing. Inmation is used as a data historian. The kafka reader can pick up the relevant kafka topics, and 'push' it to the cloud, where it can also be accessed and processed. The following figure provides an overview (Figure 7-3).

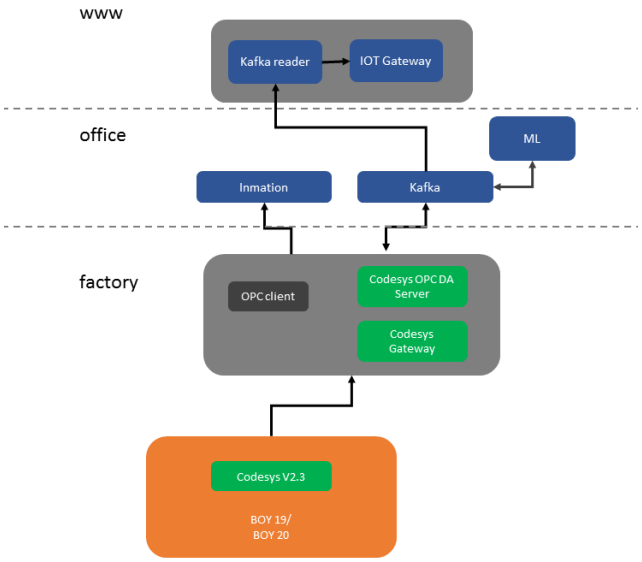

Figure 7-3 Overview of components and infrastructure

7.3.3 System requirements

The system requirements are not released because they contain confidential information.

However, the following high-level overview is provided:

- The new platform should never endanger safe operation of the equipment
- Philips will remain owner of data originating from the factory network
- No direct connection to the machine network will be made from an external network.

8 Trial 7: GESTAMP automotive part prescriptive quality assurance factory 4.0

The section consists of two main parts and provides details for trial 7:

- **Pilot overview**

Provides explanations about the manufacturing processes and plants involved in the trial. Additionally, it explains the objectives to be achieved and the partners involved.

- **Business requirements**

This section provides an overview of the business processes involved in the trial.

- **Pilot specification**

Details the technical specifications required in order to realize the solution for each trial. This includes descriptions of legacy systems to be integrated, software components, and software requirements.

8.1 Pilot overview

8.1.1 General description

Gestamp will focus on improving the efficiency and performing of the whole plant located at Navarra in Spain. The improvement will consider the optimization of multiple aspects such as energy consumption, logistics, quality and maintenance. In this sense, the future trial will be based on the implementation of smart services to optimize these aspects within four different business processes which will be essential for the improvement of the overall efficiency of the factory.

During the trial, inline inspection solutions for quality control will be integrated in order to analyse and manage quality information about great number of components as well as finished and complex products (3D pointclouds of up to 10 million points) like car chassis frame. Moreover, this new approach will allow to integrate and manage quality data from different production lines to be subsequently analysed and processed, detecting defects in an early and accurate way, getting statistics, and customized reports so that all the quality information will be stored and managed in the M3 Cloud. In this context, this data will be accessible for the models and apps developed so will be able to be used in collaboration with data from other sources, preventing major failures and waste of material.

Table 8-1 Trial 7 application domains

Application Domain*		Description and justification of the application domain
Smart Connected Production	X	1 Data integration from the different sources of data in order to get insights 2 Help on the decision making with the usage of descriptive, predictive and prescriptive analytics *3* Create simple visualization with complex analytics in order to help the user decision making

8.1.2 Objectives

Gestamp has identified Industry 4.0 as one of the main global objectives. It is materialized by different initiatives under this domain such us energy efficiency, zero defects, performance improvement, predictive maintenance or logistics. Sometimes all of these challenges meet on the same initiatives due to essential on the source of data as well as the experience resources involved. The pilot will take place on the plant that the group has in Gestamp Navarra (Spain) and will be focused on improvement of the plant efficiency, based on the analysis of the different sources of data such as process, logistics and quality information.

Regarding process' sources of data, the Manufacturing Execution System (MES) represents one of the key sources of information to be integrated. The information provided by MES is key to track and document the production process, from raw material to finished goods and would make the decision making process more efficient. It is very important to track and analyse the data in real time.

Gestamp has always identified the client as the main priority what means to meet with high quality and responsibility complex technical requirements. Under this domain, it is important to remark everything regarding to the logistics because quite often Just in Time and similar concepts are implemented on the projects. Based on it and reinforced by the research literature[3] the way to achieve it is by the transformation of the logistics into smart logistics. Thanks to the information of location in real time of forklifts and containers and the integration of this information in Gestamp production systems, will allow to have a better control of the internal logistics of the plant and to optimize it. The aim is not only to

[3] *Industry 4.0 and the current status as well as future prospects on logistics.* Computers in Industry, ISSN: 0166-3615, Vol: 89, Page: 23-34. 2017

geolocalise factory assets indoor and outdoor, but to obtain attributes of the asset, such as status, content, etc.

Finally, the quality is an important and sometimes complex measurement that has a high impact on the product and therefore on the plant efficiency. There are already several digital sources of data coexisting with manual task inspections. Sometimes the heterogeneity on the data as well as the immediate transformations on the part into final products make very complex the way to process all this information.

Regarding the objectives for this project, there can be enumerated as follows:

- The data integration from the cited sources of data. Some of this information is already available on different storage systems but the correlation and getting the insights are not implemented. For that, new architectures will need to be designed and deployed.
- The descriptive, predictive and prescriptive analytics over these sources of data are key levers on the project to transform the data into value and therefore to increase the process efficiency.
- The combination of the previous points and visualization, it is expected to help operators to take decisions. It means to show the right data on the right moment as well as to include 'push' events into the user interface that makes also to the system 'speak' into the operator for critical issues.

In summary, the main goal is the improvement and enhancement of the plant efficiency considering multiple aspects such as energy, logistics, quality and maintenance. Thus, some of the benefits expected from this project are:

1 Optimize the production process

As it is aforementioned, the aim of this trial is to deploy cutting-edge technologies to transform the current factory towards a digital, virtual and resource-efficient one.

Currently, the manufacturing lines are not as effective as they should since most of the data is not analysed and systems work independently. Through the development of innovative big data cognitive manufacturing processes, the machines and processes will be continuously monitored and the data will be processed in real time in order to enable the optimization of the machines' performance, production and plant process; improving the decision-making and reducing overall costs.

Moreover, the development of quality assurance solutions will provide competitive advantage to Gestamp and manufacturing companies in general because it helps to increase the accuracy of machines and improved controls. The improvement should not only concern the individual machines as isolated islands but encompasses the

totality of production process as a system of interrelated elements that seek to maximise efficiency, productivity, customer satisfaction; whilst at the same time eliminate waste and excess inventory.

2 Reduce inefficiencies and time losses due to unknown location of assets

The implementation of advanced technologies to localize assets in the manufacturing plant will allow to optimize the logistics process both outdoor and indoor. In addition, Gestamp will gain valuable knowledge about these assets so the process will be enhanced. Comparing this "smart logistic" with the current one, a highly number of events will decrease, obtaining lower waste time and resources and increasing the efficiency of the manufacturing process.

3 Avoidance of mistakes in product identification

The integration of real-time visibility of the evolution of the production process and the track of the different assets will permit to identify from the very first moment the multiple parts used to manufacture complex products. This great improvement will save time and costs. Furthermore, the production process will be more agile.

4 Better management of stock

The implementation of zero defect and zero breakdowns technologies will provide vast knowledge about the different materials, products, machines' performance, etc. which will be essential to considerably reduce the stock of spare parts and optimize their management since the need for them will be known in advanced and with enough time to arrange and manage their acquisition. In this sense, it could be expected that the better management of stocks will lead to a more profitable business.

5 Reduce the uncertainty for the organization

The current approach to manufacturing and network data collection and analysis does not produce immediate, actionable information. The overall impact of the current scenario is that the data is not used in a manner which allows for immediate decisions to be made. This negatively impacts the manufacturing process, in terms of inefficiencies, defects, and cost overruns, all of which decrease the overall return on investment of the company. The result of the data not being adequately captured and analyzed means that manufacturing process bottlenecks are not being properly detected.

6 A more informed organization

Connecting and mixing data from engineering, production, usage/context and consumer experience and the easy access to this data through the visualizations by all actors involved in the production plant will considerably improve the communication within the organization. This improvement will be key to optimize the production resources, capacity and quality. Hence, this will have an economic and productive impact in the manufacturing sector.

7 Supports decision makers

As it is explained, the implementation of descriptive, predictive and prescriptive analytics and the management of assets not only will allow to optimize the efficiency of the production plant but also to ease the decision-making. By connecting, sharing, processing and exploiting manufacturing data, Gestamp will be able to optimize the decision-making process, improving the product-service-system experience.

8.1.3 Participants

You can find an extended description for each of the participant in APPENDIX 1: Participant description

Table 8-2 Trial 7 participants

Gestamp	**GESTAMP** is an international group dedicated to the design, development and manufacture of metal automotive components to achieve increasingly safer and lighter vehicles.	Main partner of the pilot.
innovalia ASSOCIATION	**INNOVALIA ASSOCIATION** A non-for-profit private associated research laboratory technology in the fields of E2E cybersecurity, quality assurance for high performance CPPS systems, mobile 3D visualisation and big data cognitive analytics.	Innovalia will contribute to the pilot with the expertise and the know how on the development of ICT-based solutions in the areas of information security, software quality, M2M and mobile multimedia information services.
i2cat	**I2CAT** A non-profit research and innovation centre which promotes mission-oriented R+D+i activities	Will provide expertise in the domain of data virtualization, a concept that allows tailored

	on advanced Internet architectures, applications and services.	access to shared Big Data environments.
	ENEO TECNOLOGÍA High-tech Small and Medium Enterprise focused on development and commercialization of OSS big data cybersecurity products for Industry 4.0 and critical infrastructure protection	Eneo develops network data security management software for high performance and trust environments.
	TRIMEK One of the main manufacturers of Coordinate Measuring Machines (CMM), metrological systems, dimensional control digital platforms and solutions worldwide.	Trimek provides highly efficient, secure and flexible virtual part information management solutions for storage of massive 3D point cloud information and high-performance exchange and sharing of virtual part information.
	CAPVIDIA is the leading software developer for Model Based Enterprise interoperability. Since 1994, Capvidia has developed integrated, standalone applications and components (SDK) for CAD, PLM and CAE.	Will provide a software platform for effective communication and exchange of the engineering data defining the product (3D CAD model) combined with PMI (Product Manufacturing Information).

8.2 Business requirements

This section specifies the business requirements that the solution that will be implemented in this pilot must meet:

- Real time containers location accuracy (less than 30cm in three axes)
- Mobile asset location sensor, that provides location in piled up die storage in real time
- Provide a tag to write relevant information about what each container is carrying
- Dashboard must include a complete virtual map of the factory floor to identify the precise location of each access point and connected asset in real time

- Support specific data format according to data protection policies
- Create custom dashboards for different user profiles
- Define access rules for data, including devices and users
- All products and components should be inspected – inline inspection
- Metrology software should be powerful enough to visualize big point clouds
- Connection to different sources of metrological data
- Availability of data at any moment
- Connection and interoperability with existing system in factories (MES, ERP…)
- Ensuring cybersecurity in relation to data transfer and storage
- Allow ccomparison between process, products and similar parts (For instance, same part manufactured on different lines) across different plants
- Provide alarms considering programmable boundaries
- Capability to detect sources of problems and defects
- Provide information for predictive actions
- Design and provide easy-to-understand dashboards with KPIs status

8.3 Pilot specification

This section details the technical specifications required in order to realize the solution for trial 7. The section is organized in three sub-sections:

1. **Legacy systems**

This sub-section provides an overview of existing data sources in the factory such as databases, sensors, etc. These sources will provide the data for the solution that address the trial's business requirements.

2. **Components and infrastructure**

This sub-section provides an overview of the components that make up the solution for trial 7.

3. **System requirements**

This sub-section provides an overview of the features required to address the business requirements of trial 7.

4. **Design decisions**

This sub-section details design decisions that affect the development of the solution for trial 7.

8.3.1 Legacy Systems

The paragraph consists of a series of tables detailing the legacy systems involved in the solution for trial 7. The description includes relevant APIs, data formats, etc. along with details relevant to big data such as data volume, velocity etc.

Table 8-3 MES &ERP data (trial 7)

Legacy system name			MES &ERP data
Type			Relational database
Details	*APIs*		API REST
	Data	*Description*	Machine status Stop summary Production schedule
		Format	JSON
Big Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralized database
	Volume (size)		Under 1GB data
	Velocity (e. g. real time)		High speed Data-In-Motion (Streaming of data at a rate)
	Variety (multiple datasets, mashup)		Homogeneous data structure
	Variability (rate of change)		Near real time, data from industrial operations with a frequency of a few ms
Other Big Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*		High Veracity
	Visualization		N/A
	Data Analytics		Key information to correlate with quality and other main sources data.

Table 8-4 Quality data (trial 7)

Legacy system name			Quality data
Type			Relational database
Details	*APIs*		API REST
	Data	*Description*	The data is grouped in three main areas: measurement, attributes and characteristics. - quality measurements

			- inspection date - physical material parameter - tolerances - units - production data
		Format	JSON CSV XML
Big Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Distributed per location
	Volume (size)		A few TB
	Velocity (e. g. real time)		Medium speed – Bath of data Data captured at a rate with permanently value but not real time analysis
	Variety (multiple datasets, mashup)		Unstructured data (Different formats) Each request consist on a group of key quality values
	Variability (rate of change)		Multiple measurements per quality test, per technology and per variant but not in real time basis
Other Big Data Science (collection, curation, analysis, action - if applicable)	*Veracity (Robustness Issues, semantics)*		Quality data, high veracity
	Visualization		Diagrams, graphics etc.
	Data Analytics		Cross-correlation between different quality test as well as the production and geolocation data can provide important insights to improve the process to reduce the defects.

Table 8-5 Geolocation data (trial 7)

Legacy system name			Geolocation data
Type			Timeseries database
Details	*APIs*		ODATA connection
	Data	*Description*	Position Asset information: status, description Alarms
		Format	JSON
Big Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralized on the plant synced from several distributed gateways
	Volume (size)		A few TB per year
	Velocity (e. g. real time)		Near real time

	Variety (multiple datasets, mashup)	Homogeneous database
	Variability (rate of change)	Near real time
Other Big Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*	Accuracy of cm for critical areas and under meter for the common zones
	Visualization	Tracking location
	Data Analytics	Predictive analytics, improve routes, etc.

Table 8-6 Sensor data and 3D Metrological data (trial 7)

Legacy system name			Sensor data and 3D Metrological data
Type			Data Lakes
Details	*APIs*		API REST
	Data	*Description*	Point clouds, GD&T, Colormapping, Machine conditioning, Model based design
		Format	Txt., XML (QIF), STL+cmr, pdf, CSV, STEP
Big Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Distributed per CMM
	Volume (size)		4TB
	Velocity (e. g. real time)		150 GB/day (30 chassis per day)
	Variety (multiple datasets, mashup)		Heterogeneous datasets (Environmental parameters, machine configuration, operational data, CAD model, 3D scanner, CMM machine condition, process capacity)
	Variability (rate of change)		Multiple measurements per quality test, per part, per technology…
Other Big Data Science (collection, curation, analysis, action - if applicable)	*Veracity (Robustness Issues, semantics)*		High Veracity
	Visualization		Realistic colourmaps, diagrams, graphics, etc.
	Data Analytics		Product comparison, trends, statistics to achieve zero defect manufacturing.

8.3.2 Components and infrastructure

The paragraph consists of a series of tables detailing the components in the solution for trial 7. The description covers functionalities, data input/output, data formats, and integration needs of the components.

Table 8-7 M3 Software

ID			BC-TRIMEK-1
Responsible partner			TRIMEK
Tool name			M3 Software
Overall Description			The M3 software is a high performance software for capturing and analysing point clouds. This module allows to scan and to capture point clouds of the real pieces, in a versatile, agile and powerful way. The M3 software in combination with the 3D optical scanners can be used to develop precise and highly accurate point cloud images that can then be converted to different 3D design and modelling software. The M3 software covers the entire spectrum of metrology, regardless of device, brand or model. It works locally but is powered up by the use of the edge-powered technologies included in the global solution.
Details	*Functionalities offered*		○ Scanning physical parts/products in combination with a 3D scanner. ○ Capturing accurate point clouds to create 3D images of the real part. ○ Geometric dimensioning and tolerances. ○ Comparison between the scanned images and the original design ○ Deviation map ○ User interface ○ Big Data functionalities: rapid acquiring of massive point clouds and big data processing and multi-level visualization of complex products.
	Data input	*Description*	• Data from 3D scanner • CAD designs of real pieces
		Format	Coordinates, STEP
	Data Output	*Description*	• Point clouds • Geometrical dimensions and deviations • Colourmap with defects and deformations • Report with the results of the measurements
		Format	Txt., XML (QIF), STL+cmr, pdf
	Integration requirements		• Hardware Requirements CPU Core i3 HD 500GB minimum RAM 4GB minimum Graphic Card 1024MB minimum Database MySQL • Software Requirements OS MS Window Win7 minimum (MS WXP not supported)
	BDVA mapping		BDVA model mapping:

		• Data Visualization & user interaction • Data processing • Development – Engineering and DevOps

Table 8-8 M3 Workspace

ID			BC-TRIMEK-2
Responsible partner			TRIMEK
Tool name			M3 Workspace
Overall Description			M3 Workspace is a cloud based metrology software that synchronizes with the main M3 Metrology software which allows for the automated uploading of any metrology results straight to the cloud. M3 workspace is web based and allows users with access to visualize the results (Point clouds, CAD models, Color mapping, Reports, etc.) using any smart device. In addition, M3 Workspace acts as a sort of repository where all the results that come from the measurements are located and can then be easily downloaded for further analysis. It permits the massive management of digital parts and point clouds, storing and sharing the metrological information.
Details	*Functionalities offered*		1. Cloud solution 2. Automatic uploading of metrology information 3. Data visualization 4. Data sharing 5. Quality data management 6. Respository 7. User interface Big Data functionalities: collaborative cloud environment where data from different sources and locations can be uploaded and visualised.
	Data input	*Description*	• Point clouds • CAD models • Colour maps • Reports • GD&T results
		Format	Txt., XML (QIF), STL+cmr, pdf
	Data Output	*Description*	• Point clouds • Geometric dimensions and deviations • Colourmap with defects and deformations • Report with the results of the measurements
		Format	Txt., XML, STL+cmr, pdf
	Integration requirements		API, web service
	BDVA mapping		1. Data Visualization & user interaction 2. Data processing 3. Data Management 4. Communication and Connectivity

		5. Cybersecurity and Trust

Table 8-9 3 Analytics

ID			BC-TRIMEK-3
Responsible partner			TRIMEK
Tool name			M3 Analytics
Overall Description			The M3 analytics is a powerful tool that enables the visualization, the statistics analysis and the reporting operations related to all the data stored in the cloud by means of several algorithms and computational components. As this tool makes use of the memory and computational resources available in the cloud, it is possible to use it anytime and anywhere and by means of a simple computer or tablet with low computational capacities.
Details	*Functionalities offered*		1. Data visualization 2. Statistics analysis 3. Perform trends 4. Reporting operations 5. Correlate production and product data 6. Knowledge extraction 7. Predictive actions 8. Create control dashboards Big Data functionalities: advanced analysis of quality data
	Data input	*Description*	• Point clouds • CAD models • Colour maps • Reports • GD&T results
		Format	Txt., XML (QIF), STL+cmr, pdf
	Data Output	*Description*	• Trends • Histograms • Reports • Cp and Cpk statistics etc.
		Format	pdf
	Integration requirements		API
	BDVA mapping		1. Data Visualization & user interaction 2. Data processing 3. Data Analytics 4. Data Management 5. Data sharing platforms 6. Communication and Connectivity 7. Cybersecurity and Trust

Table 8-10 Ultra-Wide Band (UWB) Positioning

ID			BC-i2CAT-1
Responsible partner			I2CAT
Tool name			Ultra-Wide Band (UWB) Positioning
Overall Description			UWB Positioning software is responsible for calculating the relative positions of each UWB tag against multiple UWB anchors. Using triangulation the system can locate an asset inside the factory. UWB Positioning runs in any Linux based Operating system. UWB Positioning allow other aplications to get each device location thanks to a pub/sub interface. It also contains an input file in which the different parameters of the UWB anchors can be changed over the air, without network collapse.
Details	*Functionalities offered*		1. Anchor position input 2. Automatic trilateralisation algorithm 3. Positioning enhancement with softening techniques 4. Easy deployment 5. Adjustable output data format 6. NTP synchronisation Big Data functionalities: massive data generation in real time.
	Data input	*Description*	• Anchor position • Tag ID relative distances • Positioning algorithm softening parameters
		Format	.txt .csv .py .conf
	Data Output	*Description*	• Current anchor positioning • Real time UWB tag positioning
		Format	.json
	Integration requirements		API, web service
	BDVA mapping		Data processing, Data Management, Communication and Connectivity

Table 8-11 I2Tracking

ID			BC-i2CAT-2
Responsible partner			I2CAT
Tool name			I2Tracking
Overall Description			I2Tracking is a unique software developed by i2CAT. It is designed to provide seamless integration between positioning technologies like UWB, BLE, GPS and RFID readings, matching each event to a specific location and determining the different states of the objects that are being moved around different areas.

Details	*Functionalities offered*		1. Central unit linux pocessor 2. RFID integration 3. UWB, BLE integration 4. Data visualisation 5. NTP synchronisation Big Data functionalities: massive data generation in real time.
	Data input	*Description*	• Tag positioning • RFID readings • Georeferences of different zone activities
		Format	.txt, TTL TX/RX, .csv, .py .conf
	Data Output	*Description*	• Real time event server • Real time visualisation • Event data base
		Format	.json
	Integration requirements		API, web service
	BDVA mapping		Data Visualization & user interaction, Data processing, Data Analytics, Data Management, Data sharing platforms, Communication and Connectivity

Table 8-12 Scalable industrial data

ID			**BC-i2CAT-3**
Responsible partner			I2CAT
Tool name			Scalable industrial data
Overall Description			Scalable Industrial data is a distributed data solution that creates a modular pipeline of data from its acquisition to its external sharing. The data can be obtained at several points in the chain between the collection and the external distribution (sharing). Using this approach, a data consumer (application) can be seamless moved around the chain and placed closer to the data collection or closer to the data sharing, depending on the requirements.
Details	*Functionalities offered*		1. Data brokerage 2. Seamless portability 3. Scalability 4. Modularity 5. Resusability Big Data functionalities: Scalable Big Data collection and distribution
	Data input	*Description*	• Raw distance data • Accelerometer measurements
		Format	csv,
	Data Output	*Description*	• Raw data
		Format	.json, csv.

	Integration requirements	Rabbit MQ IDSA connector WSO2 middleware
	BDVA mapping	Data Management, Data Protection, Data Processing, Communcation and connectivity, Standards, Data sharing platforms, Cybersecurity and trust

Table 8-13 redBorder

ID			BC-ENEO-1
Responsible partner			ENEO
Tool name			redBorder
Overall Description			redborder is a real-time NTA (Network Traffic Analysis) and active cybersecurity platform based on Big Data and Open Source. redborder provides the platform upon which Apps (software plugins) and Probes (stand-alone modules running outside the platform) can actively collect data in the network and enforce policies (e. g. block specific malicious traffic). redborder provides NTA, real-time location analytics, active cyber security
Details	*Functionalities offered*		1. Network traffic analysis 2. Data analytics 3. Data visualization 4. Data management 5. Data enrichment 6. User interface
	Data input	*Description*	• Connected asset location (Wi-Fi) • Machine Use and availability (MES) • Network activity and use
		Format	JSON
	Data Output	*Description*	Visualization of location and activity of connected manufacturing assets in real time. Visualization / analysis of manufacturing data in real time.
		Format	JSON
	Integration requirements		MES/ERP, REST API
	BDVA mapping		Data Visualization & user interaction, Data processing, Data Analytics, Data Management, Data sharing platforms, Development – Engineering and DevOps, Communication and Connectivity, Cybersecurity and Trust

Table 8-14 MBDVIdia and MBDVidia for Creo

ID	BC-CAPVIDIA-1

Responsible partner			CAPVIDIA
Tool name			MBDVIdia and MBDVidia for Creo
Overall Description			Capvidia MBD/MBE solutions are based on utilization the QIF standard. With powerful tools enabling visualization of the Product Manufacturing Information Data (PMI) with the semantic representation allowing the user to achieve high level of machine to machine communication reducing the human factor to the minimum.
Details	*Functionalities offered*		1. G&T and FTA Data visualization and access 2. Metrology features automatic reconstruction 3. Bill of Characteristics 4. FAI, First Article Inspection 5. Reports 6. Excel binding 7. Correlate metrology data with the CAD model 8. Deviation analysis 9. CAD traceability 10. MBD ready check, MBD model repair
	Data input	*Description*	• B-REP model with the 3D Annotation • CAD models in the CAD native format • Measurement data visualization • Reports • GD&T and FT&A access
		Format	QIF, STEP AP 242, CAD Native (prt..CATPart, etc.)
	Data Output	*Description*	• Excel • Reports • Cp and Cpk statistics, etc.
		Format	Pdf, HTML, QIF, Excel
	Integration requirements		Standalone version, CAD Plug-IN, API
	BDVA mapping		

8.3.3 System requirements

The paragraph consists of a series of tables detailing the software requirements in terms of features addressing the business needs of trial 7. The details include, associated business requirements, an overview of the functionality, data input/output, relevant software requirements of the feature, interfaces, performance and other non-functional requirements.

Table 8-15 System Requirement SR-WP7-T2.1-1

ID	SR-WP7-T2.1-1

Business requirement reference	Business scenario 1: Real-time Indoor Assets location platform optimization and secure data	
Overall Description	- Gateway data acquisition. - Handover & triangulation of the diff geolocation data sources to get the expected location. Requirements -Data ETL to produce alarms, visualization, analysis.	
Feature	*Introduction & Purpose of feature*	Collect, process, analyse and visualize de geolocation data
	Stimulus Response Sequence	The application follows the ETL dataflow
	Functional Requirements	• Data acquisition with data quality analysis near real time
External Interface Requirements	*User Interfaces*	• Web responsive reachable by laptop, tablet or smartphone with user authentication
	Hardware Interfaces	• Industrial PC • Mobile devices to access visualization, push notifications, etc.
	Software Interfaces	Alarm & visualization for assets routes platform
	Communications Interfaces	• ODATA for interface with other Industry 40 software as well as the internal communication between gateway and central hub plant
Performance Requirements		• Real time on the data acquisition, process, analysis and visualization. • Web responsive
Other non-functional requirements		N/A

Table 8-16 Software Requirement SR-WP7-T2.1-2

ID	SR-WP7-T2.1-2
Business requirement reference	Business scenario 2: ZDM powered by massive metrology
Overall Description	- Massive point clouds processing. - Multi-level visualization of massive point clouds and colourmaps. - Unique QIF metrology workflow including product design data. Agile management of massive metrological data. - Collaborative environment for quality data. - Advanced analysis of quality data

Feature	*Introduction & Purpose of feature*	Massive metrological data processing, visualization, storage and analysis.
	Stimulus Response Sequence	Input & output description QIF workflow
	Functional Requirements	- Rapid acquisition and processing of the product data - Multi-level Visualization (colourmaps with textures) - Multi-level quality analysis at component and product level. - Generation of the QIF model, joining CAD and PMI - Implementation and automation of the metrology workflow, starting from the QIF MBD up to the advanced analysis of the metrological results - Ensure interoperability - Optimization of the measurement plans - Generation of the inspection program - Ensure traceability of products and data - Connection to different sources of metrological data - Development of the required IDS connectors using Fiware technology for data sharing - Development of a framework capable of storing and managing big volume of heterogeneous metrological data - Data access - Ensuring cybersecurity in relation to data transfer and storage - Knowledge extraction - Advanced analysis like statistics and trends - Provide alarms considering programmable boundaries - Range time - Visualization - dashboard - Export to PDF
External Interface Requirements	*User Interfaces*	Web interface where the user will select the time ranges, thresholds and analysis applied on the data
	Hardware Interfaces	Server, global quality database
	Software Interfaces	Web responsive environment
	Communications Interfaces	API
Performance Requirements		Batch analysis with horizontal scale up architecture
Other non-functional requirements		N/A

8.3.4 Design decisions

Table 8-17 Design decisions in Trial 7

Component ID	Component Name	System Requirement References	Comments
BC-TRIMEK-1	M3 Software	SR-WP7-T2.1-2	
BC-TRIMEK-2	M3 Workspace	SR-WP7-T2.1-2	
BC-TRIMEK-3	M3 Analytics	SR-WP7-T2.1-2	
BC-i2CAT-1	UWB Positioning	SR-WP7-T2.1-1	
BC-i2CAT-2	I2Tracking	SR-WP7-T2.1-1	
BC-I2CAT-3	Scalable industry data	SR-WP7-T2.1-3	
BC-ENEO-1	Redborder platform with Traffic, Vault, Mobility and IPS modules	SR-WP7-T2.1-1	
BC-CAPVIDIA-1	MBDVIdia and MBDVidia for Creo	SR-WP7-T2.1-2	

9 Trial 8: Volvo truck digital assembly factory 4.0

The section consists of two main parts and provides details for trial 8:

- **Pilot overview**

Provides explanations about the manufacturing processes and plants involved in the trial. Additionally, it explains the objectives to be achieved and the partners involved.

- **Business requirements**

This section provides an overview of the business processes involved in the trial.

- **Pilot specification**

Details the technical specifications required in order to realize the solution for each trial. This includes descriptions of legacy systems to be integrated, software components, and software requirements.

9.1 Pilot overview

9.1.1 General description

The scope of Volvo use case is from Umeå Cab factory at the point when the painted cabs are put on the racks for transportation. The transportation process is handled by external companies. Then it arrives at final assembly plant at Tuve located in Gothenburg. At Tuve plant the cabs are feed into the main line for final assembly, and that is the end point of Volvo use case. The Umeå plant is the internal supplier for cabs to the final assembly plant in Tuve. The distance between these two plants is about 987 km. A short description about Umeå plant and Tuve is presented here.

Umeå plant

The Umeå factory is located next to the Ume River in the city of Umeå. The factory was founded by Gösta Nyström (1906-1988) in 1929 and owned by Volvo since 1964. The Umeå cab plant produces cabs for Volvo FH, FM and FMX, from steel coil to painted cab. The Umeå plant has a high technical level and the employees are skilled in their different roles in order to secure that products are always delivered in the right time and also according to the high quality demands our customers have. Besides delivering cabs to the chassis

plants, the cab factory sends KD and PKD with cab parts all over the world to other Volvo plants. The capacity is 75.000 cabs per year.

There are three processes at this plant:

1. **Pressing & Part Production:** Pressing and Parts Production transform steel coils to cab parts and cab details that transport to Body In White (BIW) department and also to other factories around the world. Customer Adaptations cabs are also produced.
2. **Body In White:** BIW is the department where the pressed parts are assembled before the cabs enter the Paint shop process.
3. **Paint shop:** The cabs are painted into different layers in the Paint shop process. There are over 850 different colors that have been painted at the plant so far.

Figure 9-1 Layout of the Umea Plant

Tuve plant

The Tuve plant is responsible for manufacturing and assembly of complete heavy-duty trucks and providing overseas material. The product range comprising of Volvo FH, FH16, FM, and FMX. Around 2000 employees work at the Tuve plant.

We manufacture trucks in the premium segment. This means that our customers have particularly high expectations of our products. They expect us at the Tuve plant to do a first-class job. They rely on our trucks to deliver the highest standard of operation and performance at all times. The high quality of assembly also enables us to maintain high delivery precision. 60 percent of the trucks produced at the Tuve plant is adapted to meet specific customer requirements.

Operations are divided into five business areas and cab trim is one of the areas. 120 cabs are produced every day, 80 by the day shift and 40 by the evening shift. Cab Trim supplies cabs for both Tuve's own truck production and for our KD plants. Figure 9-2 shows the layout of the plant in Tuve.

Figure 9-2 Layout of the Tube Plant

Table 9-1 Trial 8 application domains

Application Domain*		Description and justification of the application domain
Smart Connected Production	X	*How our trial is connected to smart connected production:* • *Connecting the logistics flow* • *Information is shared through the whole flow e. g. where the component is located between Umeå and Tuve and when it is changing transportation state* • *Visualizing data and information about the status* • *Provide decision support* • *Control tower – connect humans in the logistics flow and in production* • *Big data analysis – learn from data* • *Data analytics – predict the trend*

9.1.2 Objectives

The objective of the implementation of the trial for the end user perspective is to address the current challenges that exist for the supply chain between two production plants. To encounter the challenge a solution is desired that can track the components cabs in this trial, from the cab production plant located in Umeå to the final assembly plant located in Tuve, Gothenburg. The components are transported on racks so another objective is also to enable the tracking of them in the returning flow back to the Umeå plant. Besides tracking and providing real-time information of the location of components (cabs) and the material

handling equipment (racks) for better planning in production and optimizing the processes, the data that is collected over time is expected to provide insights about the trend by analyzing the big data sets. From the overall objective of this trial, six benefits have been identified with a description of the impact on the organization.

Benefit 1 – Reduction of costs: By having real-time information about where the components are located during the transport from the cab supplier to the final assembly, better decisions support will help the organization in the planning process. The organization can with real-time evaluate when they will have the components available for the final assembly and avoid unplanned production stops due to missing materials. The potential to have better planning procedure that can help them to avoid production stops can support in reducing the cost that missed production time imply. Another aspect that can have an important impact on the cost, is the potential of evaluating the number of racks that are actually needed based on demand and that the racks are tracked back to the cab production. In the current situation, racks are lost in the transportation between the two sites which involve costs. To always have information about where components are located would also provide the organization with more data and insights to understand the logistics chain, which can have the positive effect of the more cost-effective logistic chain.

Benefit 2 - Effectiveness of processes: By the implementation, a second benefit that has been recognized is the ability to develop the own processes. By having better data about the logistic chain in real-time but also larger data sets over time, can help the organization to optimize their planning of logistics. Also, by having better data available, the forecasting will provide a more reliable decision support of when they can start production and what they will have available that should correspond to the customer demand. If a delay should occur in the logistic chain between two sites, this will be known by the organization because the tracking of the components will provide this data and the organization will have decision support that can help them to re-plan production. The implementation of the pilot also supports the processes by enabling the organization to monitor, analyze, and predict the supply chain.

Benefit 3 - Visualization of data: As data of the supply chain becomes available, this could be visualized for the organization. By visualizing, the data will be transparent to the organization and provide fact-based decision support of where things are in the supply chain. The visualization will have the positive impact on reducing the uncertainty within the organization. The uncertainty that has previously existed when a component can be delivered and when production can start will be reduced by the support of this implementation. The organization will measure more and hence now more about the status and their processes. The visualization will also provide decision support to the decision maker e. g. when production can start depending on the delivery of the needed component.

Benefit 4 - Learn from data: As the data from the logistic chain is made available an additional benefit for the organization to have more and more data available over time and learn from the data. Trend analysis of data that can provide new insight of the behavior of the system, providing data that give better decision support over time, understand what the main bottlenecks are and where the problems occur, root cause analysis, and identify patterns in the data that were not previously known since the data was not available, to mention some impacts.

Benefit 5 - Applying blockchain: Benefits of applying blockchain in this scenario are merely due to visibility and transparency of the process to all parties on the business network, traceability and traceability of the parts (racks and cabs), provenance, and a non-repudiation process.

Benefit 6 - Increasing the digitalization level within the company: The general trend within the manufacturing field is to transform into the more digitalized organization that make use of the digital technologies to a larger degree. For Volvo to keep up and stay relevant to the international market, another benefit of the implementation of the pilot is the opportunity to increase the digitalization level of the company.

9.1.3 Participants

You can find an extended description for each of the participant in APPENDIX 1: Participant description

Table 9-2 Trial 8 participants

	VOLVO TRUCK Is one of the leading suppliers of commercial transport solutions providing products such as trucks, buses, construction equipment, and drive systems for marine and industrial applications.	Main partner of the pilot.
	CERTH/ITI CERTH/ITI is an organization devoted to the promotion and execution of research in the area of informatics and telecommunications.	Will contribute to the pilot with the expertise on process modeling and the development of simulation platforms and visual analytics for highly complex systems, ontologies, and

		semantic matching, sensing and signal processing, big data manipulation and forecasting for industry and e-business.
IBM	IBM is an international company. IBM Research – Haifa is involved in the most promising and disruptive technologies, including AI, blockchain, and quantum computing.	Will be responsible for the applicability of Blockchain technology to the project use cases.
CHALMERS	CHALMERS The division of Production Systems at Chalmers works with the sustainability and competitiveness of industrial production systems. The research area is system-oriented and requires knowledge about both the system as a whole and its separate components, for example humans, automation and processes.	Will assist the pilot with its expertise and knowledge on Big Data on industrial production systems.

9.2 Business requirements

This section specifies the business requirements that the solution that will be implemented in this pilot must meet:

- Provide an accurate and easy to use monitoring system for the racks transportation from Umea to Tuve
- Accurate forecasts of arrival time of cabs/racks available to planning manager
- Events with possible delays automatically sent to the planning manager
- Stakeholders in the process should cooperate in the new scenarios

9.3Pilot specification

9.3.1 Legacy Systems

The following high level overview is provided for the legacy systems to be integrated in trial 8:

Table 9-3 Trial 8 legacy sytems overview

Dataset name	Data Source Location	Data Owner	Velocity (streaming)	Variety (forms)	Volume (scale)	Veracity (uncertainty)
Central Planning Office	Volvo ERP System	Volvo	Medium	High	Very high	high
Chassis sequence optimiser	Volvo ERP System	Volvo	Medium	Medium	Medium	High
Track and Trace for Cab transportation	Oracle IOT platform	Volvo	Medium	Medium	Medium	High

9.3.2Components and infrastructure

The paragraph consists of a series of tables detailing the components in the solution for trial 8. The description covers functionalities, data input/output, data formats, and integration needs of the components.

9.3.2.1 CERTH Data analytics tool

Table 9-4 CERTH Data analytics tool

ID	BC-CERTH-1
Responsible partner	CERTH
Tool name	CERTH Data analytics tool
Overall Description	CERTH Data analytics tool will support predictive analytics models and techniques that will enable the forecasting of cabs arrival time and will enhance the decision making over the supply chain. The tool will build upon a CERTH IoT platform able to support Big Data Storage and analytic functionalities. The predictive analytics tool will be based especially on logged data for GPS sensors that will be available to the IoT platform. Furthermore, this tool will be able to query data from the blockchain (data from beacons or GPS in some critical point of the transportation). Beside this, many other factors will be taken into consideration by the analytics tool such environmental parameters, timetables related to the transportation and a big amount of historical data coming from VOLVO and they are related to assembly line in order to associate delays with

	assembly line scheduling and optimize the assembly line planning. Plenty of statistical and machine learning methods will be applied in order to provide the highest possible level of accuracy of the forecasting estimations.		
Details	*Functionalities offered*		• Data storage • Data analysis • Data processing • Prediction and forecasting mechanisms • Assembly Line Optimization mechanism • User interface / visual analytics
	Data input	*Description*	• Sensor data from GPS trackers and beacons • Logs from the Hyperledger Fabric Blockchain • ERP Data (historical data, assembly line data) • Data about train timetables, routes, truck transportation data etc. • Weather data coming from APIs
		Format	Data model(vocabulary) defined by technical partners in JSON format
	Data Output	*Description*	• Analysis results, forecasting of delays in racks and cabs transportation, estimation of arrival time, optimal assembly planning
		Format	JSON, events/messages, visualization using graphs etc.
	Integration requirements		MES/ERP, IBM Hyperledger Fabric, APIs
	BDVA mapping		• Data Visualization & user interaction • Data processing • Data Analytics • Data Management

9.3.2.2 Hyperledger Fabric

Table 9-5 Hyperledger Fabric

ID	BC-IBM-1		
Responsible partner	IBM		
Tool name	Hyperledger Fabric		
Overall Description	Hyperledger Fabric is permissioned blockchain framework. It provides a modular architecture with a delineation of roles between the nodes in the blockchain network, execution of smart contracts and configurable consensus and membership services. At the heart of the framework is distributed ledger for immutable recording of transactions occurring in the network. The Fabric infrastructure is built in such a way as to deliver high degrees of confidentiality, resiliency, flexibility and scalability.		
Details	*Functionalities offered*		1. Distributed ledger- immutable transaction log (data management)

			2. Business logic implemented by smart contracts (data processing) 3. Data privacy
	Data input	*Description*	• Transaction data related to assets on the network
		Format	Structured data
	Data Output	*Description*	• Events, transaction data
		Format	Structured data
	Integration requirements		RESTful APIs, Hyperledger Fabric SDKs for transaction invoke and quering functions (NodeJs, Java)
	BDVA mapping		1. Data Protection 2. Data Management 3. Data sharing platforms

9.3.2.2.1 Detailed Description

Hyperledger Fabric is a private permissioned blockchain framework. It is a platform rather than a component, allowing for different parties participating in the blockchain network to share their data in a secure and controlled manner, governed by a consensus of all relevant parties. Each participant in the network will have the same immutable copy of the distributed data ledger, allowing for transparency, provenance, non-repudiation, increase of trust and efficiency, and cost reduction inherent in more efficient processes.

Hyperledger Fabric offers at its core a distributed ledger for storing the transactions, and smart contracts – "chaincode" in Fabric - code running on top of the ledger and allowing consistent update of information — and to enable a whole host of ledger functions (transacting, querying etc.) — a blockchain network uses **smart contracts** to provide controlled access to the ledger.

Where Hyperledger Fabric breaks from some other blockchain systems is that it is **private** and **permissioned**. Rather than an open permissionless system that allows unknown identities to participate in the network (requiring protocols like "proof of work" to validate transactions and secure the network), the members of a Hyperledger Fabric network enroll through a trusted **Membership Service Provider (MSP)**.

Data sovereignty: Hyperledger Fabric is a platform for shared data. The purpose of the distributed ledger is to allow all participants the transparency and immutability of the shared data and thus to increase trust and serve as the single and ultimate "source of truth". Once written on the ledger, the transaction is immutable – it cannot be changed. Fabric provides several mechanisms allowing for data sovereignty and permissioned access to data, including the privacy mechanisms inherent in the network itself

(permissioned access only), the concept of channels, encryption of data, and user roles allowing partial access to data to different network participants.

9.3.3 System requirements

The paragraph consists of a series of tables detailing the software requirements in terms of features addressing the business needs of trial 8. The details include, associated business requirements, an overview of the functionality, data input/output, relevant software requirements of the feature, interfaces, performance and other non-functional requirements.

Table 9-6 Software requirement SR- WP7-T2.2-1

ID		SR- WP7-T2.2-1
Business requirement reference		a) Forecasts about the arrival time of racks/cabs should be available to Planning manager b) Events with possible delays should be send to the planning manager c) Provide a monitoring system for the racks transportation
Overall Description		Data from the installed GPS trackers are stored to an IoT platform part of Data analytics and forecasting. Critical points of the transportation are stored at the chain of IBM Hyperledger Fabric. After that, they are available to the data analytics tool using a common data model for the description of data and the services of developed APIs. The analytics engine uses predictive analytics models and techniques on data stored at blockchain, historical data, live GPS data as well in order enable the forecasting of cabs/racks arrival time and triggers events for the delays. Moreover, a real time monitoring system/interface based on real time information coming from sensors will be available to the planning manager. Benefits and objectives: • Follow the status of racks in the transportation and enable the fully visibility of the supply chain • Forecasting of the arrival time of Cabs and re-plan cab trim and final assembly line. Forecasting of the arrival time of racks in the return flow
Feature	*Introduction & Purpose of feature*	Fully visibility of supply chain, forecast of cabs/racks arrival time
	Stimulus Response Sequence	Cab transportation progress
	Functional Requirements	System shall predict the arrival time of cabs/racks System shall inform for delays Basic milestones of the transportation should be stored at blockchain for the visibility of supply chain • System shall monitor all the process of transportation
	User Interfaces	• User monitor all the process of transportation • User get informed for delays

External Interface Requirements	*Hardware Interfaces*	IBM Hyperledger Fabric will be connected with GPS devices and beacons. Also IoT platform will be connected with GPS devices. The analytics component over the IoT platform is connected only with other software components
	Software Interfaces	IBM Hyperledger Fabric, APIs (e. g. IoT platform APIs, weather APIs)
	Communications Interfaces	REST HTTP Endpoints in order to query data from Hyperledger Fabric blockchain and send predictions/events to monitoring framework. MQTT and REST APIs for IoT platform connections
Performance Requirements		-
Other non-functional requirements		-

Table 9-7 Software requirement SR- WP7-T2.2-2

ID		SR- WP7-T2.2-2
Business requirement reference		Assembly Line Optimization
Overall Description		The system should be able to provide solutions for re-plan cab trim and final assembly line by using the predictions in supply chain and assembly line information from pilot systems
Feature	*Introduction & Purpose of feature*	Optimization of assembly planning
	Stimulus Response Sequence	Suggestions: • assembly line re-planning • supply chain optimization
	Functional Requirements	• System shall make suggestion for the optimization of assembly planning • Supply chain forecasts should be available to assembly optimization engine • Assembly line data (processes, processes duration, process steps, bill of material etc.) should be available to optimization engine
External Interface Requirements	*User Interfaces*	• Proposal for assembly line re-planning are available to user (possible interactive UI is under investigation)
	Hardware Interfaces	The analytics component over the IoT platform is connected only with other software components that provide data
	Software Interfaces	Assembly data sources, Supply chain forecasting tool
	Communications Interfaces	REST HTTP Endpoints
Performance Requirements		-
Other non-functional requirements		-

9.3.4 Design decisions

Table 9-8 Major design decisions

ID	Description	Justification	Relevant system requirements
BC-CERTH-1	The **Data analytics tool** will build upon the **CERTH IoT**. The data will be extracted: - from the blockchain through **REST APIs** - through **IDS Connectors** - from **Open Data APIs (REST)**	- The **IoT platform** provides the infrastructure to store (MongoDB and InfluxDB) and analyze data in the cloud, connection through MQTT and HTTP protocols, offering security (authentication and authorization mechanisms) and easy UI integration (based on AngularJS and a template similar to FUSE). - It is an already developed system that supports a smart home with plenty of IoT devices and data/visual analytic services. This platform fits well with VOLVO scenario which is based on IoT devices and data analytics. The platform will be extended in order the new version/instance will cover the BOOST 4.0 needs. - **MQTT** provides security and reliability, as well as instant communication. - **REST API** is an independent interface between systems characterized by flexibility and portability. - **IDS connectors** provide secure data exchange and is able to communicate with every	• SR- WP7-T2.2-1 • SR- WP7-T2.2-2

		other connector or component in the ecosystem of the Industrial Data Space.	

Table 9-9 Components used in trial 8

Component ID	Component Name	System Requirement References	Comments
BC-IBM-1	Hyperledger Fabric	SR- WP7-T2.2-1 SR- WP7-T2.2-2	Facilitates the implementation of these requirements.
BC-CERTH-1	Data Analytics and Forecasting tool	SR- WP7-T2.2-1	Data Analytics and Forecasting tool is based on an IoT platform. The component offers Data Visualization & user interaction, Data processing, Data and predictive Analytics and Data Management

10 Trial 9: Whirlpool whitegoods spare part sensing customer service factory 4.0

10.1 Pilot overview

10.1.1 General description

The trial in whirlpool will involve different functions inside the organisations with different roles:

- **Consumer Service and Quality** that is also the main actor and beneficiary of the trail and it's mainly located in Fabriano (AN) plus in 35 national sales organisation (NSO)
- **Manufacturing** with manufacturing sites in 7 countries
- **Global Product Development**
- **Market Operations, Product and Brand** located in Pero (HQ) plus in 35 national sales organisation (NSO)

some of them will be only data providers while other functions will be both data providers and data consumers. Here below a graphical representation with the evidence of the data providers (in green) and data consumers (in orange):

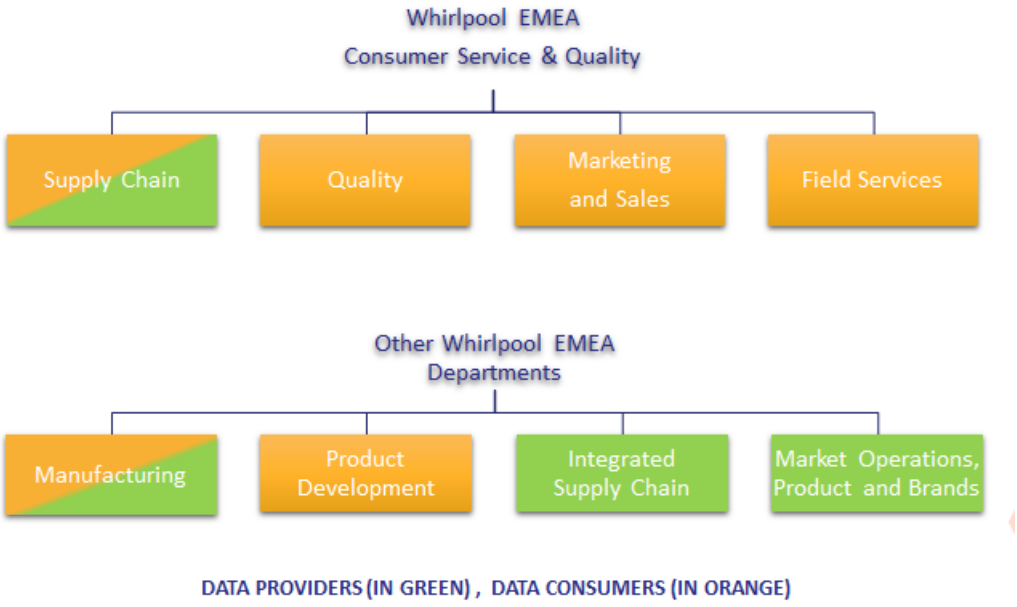

Figure 10-1 Pilot roles

The main facility impacted by the trial benefits is located in **Carinaro** (CE) – Italy where the following basic processes are performed with the goal of serving spare parts, accessories and cleaning products into all the EMEA regions:

1. Inbound from Factories and Suppliers
2. Prepacking and Labelling
3. Kitting
4. Put away
5. Picking, Packing and Order Preparation
6. Shipments Execution

The Supply Chain of the Whirlpool Service Network is currently organised with a central warehouse based on Carinaro (Italy – Caserta) as described above that is also the main entry point of the spare parts replenishment from factory and suppliers plus 8 regional SPC (Spare Part Centres) distributed around the EMEA perimeters.

Those 9 main SPCs are serving more than 30 National Sales Organisations processing every day more than 12.000 delivery lines* for both spares' parts and accessories requests. Regional SPCs are replenished mainly from the main Central Warehouse but also directly from factories and suppliers as per the following schema:

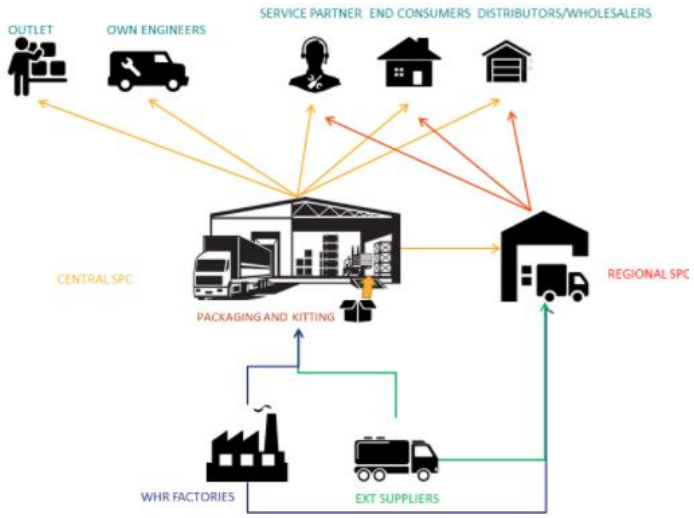

Figure 10-2 Regional SPCs process

In addition to that (but out of scope from the pilot project) we have 32 local warehouses mainly used for returns and a large number of Technician Van (where the country is served by Whirlpool owned technician).

Table 10-1 Trial 9 application domains

Application Domain*		Description and justification of the application domain
Smart Digital Engineering		
Smart Production Planning & Management		
Smart Operations & Digital Workplace		
Smart Connected Production		
Smart Maintenance & Service	X	*The trial is confined into service supply chain perimeter and is mainly oriented in improving the availability of the spare parts needed for product repairs reducing as much as possible the stock values hold in the warehouses.*

10.1.2 Objectives

The main objective of the whirlpool trial is the optimisation of the spare parts planning and distribution process in the EMEA region through the full adoption of a prediction tool and technique that can help the organisation to better estimate when and where a spare part is needed. The procurement of the components, the production and distribution of a spares is currently triggered by a statistical forecast based only on historical demand of the spares without taking into consideration other important endogenous variables that can contribute to explain what is really happening in the market.

The current process is under the responsibility of the whirlpool consumer service supply chain function that is also directly responsible for the level of inventory kept in every single spare part centre in EMEA and for the service level given to the customers. The current stock level could be overall reduced and the availability (and thus the service level) could be increased if we will be able to better estimate the future needs of spare parts on time.

The relevant information identified and needed should be derived from big data coming from different departments of the whirlpool organisation:

1) from every single factory that is producing the appliances we can retrieve the test data, estimate the life duration of the appliance and intercept every change on the components that may affect the defectiveness of the different models produced; Moreover every change applied into the production of an appliance to fix

defectiveness is directly connected to a decries of spare part consumption in the future;

2) from the market operations we can retrieve the sell in and the data coming from the usage of the connected appliances in order to initiate a predictive maintenance approach and estimate the overall installed base;
3) from consumer service field function, we can retrieve the data registered after the service calls in order to estimate the real defectiveness of our appliances in the field and also feedback factory and engineers to take immediate corrective actions.

The envisaged BD Solution is made by a Spare Parts Prediction Tool and by a Real Time monitoring and reporting system.

The Prediction Tool

The main IT result of the trial is the generation of a new statistical forecast that will be used to predict the future demand of each single stock keeping unit (SKU) per each national sales organisation (NSO). The result of this elaboration will be then used by the customer service planning team in order to:

- procure, produce and distribute spare parts in the network on the short-term horizon
- budgeting and long-term forecasting to suppliers and factory

As explained in the previous paragraph this new tool will incorporate the elaboration of the big data (coming from different functions and databases already present in several whirlpool departments but not yet used for planning purposes) in order to:

1) identify outliners, patters and components of the historical time series;
2) identify events that will change the consumption trend of a spare parts ahead of time;
3) choose the best statistical model for every spare code and apply the needed correction real time based on consumers feedbacks;
4) produce alerts and reports to support supply chain decisions;
5) Produce monitoring and analysis of real-time data from connected appliances in order to provide the users with new business information to manage damages and alerts on-time.

Moreover, also external data sources available on the web needs to be integrated that may help in a better understanding of the end consumers demand.

The Real Time Monitoring and Reporting System

1) The other ambition of the pilot is to provide real-time information about data elaboration and a set of reports to be used by different actors inside the

organisation in in order to: monitor system performances, forecast error, demand trend and historical time series decompositions;

2) Feedback Product and Process development and on abnormal peaks of claims, failures, request of parts in order to plan for technical solutions on product design and process design;
3) Feedback Markets on abnormal peaks of claims, failures, request of parts in order to plan for technician training and be prepared to future consumer requests.

10.1.3 Participants

You can find an extended description for each of the participant in APPENDIX 1: Participant description

Table 10-2 Trial 9 participants

Whirlpool	WHIRLPOOL Is the world's leading manufacturer and marketer of home appliances.	Main partner of the pilot.
sas THE POWER TO KNOW.	SAS is the leader in analytics: it helps organizations turn data – about customers, operations, financials, security and more – into information they can apply to solve day-to-day issues and reach long-term goals.	SAS will provide the pilot with the Big Data tools for visualization, analysis and processing.
POLITECNICO MILANO 1863	POLITECNICO DI MILANO is the most important technical university in Italy and one of best in Europe, according to recent rankings	Will contribute with its Big Data Factory 4.0 expertise, and will be in charge of the alignment between the pilot technical architectures with the Reference Architecture

10.2Business requirements

- Create a central database and data model, extracting relevant data form the company's databases
- Analyse and consolidate historical demand
- Consider seasonality where present
- Generate short and medium-long term forecasting for each SKU/NSO, and calculate de forecast error
- Review safety stock formula to react to real service level of suppliers
- Use data coming from smart appliances and match with service orders confirmations
- Recognise patterns and defectiveness correlations
- Alert and reporting tool to be used by all the involved to analyse results and take decisions
- Identify spare parts needed to fix the defect in order to plan it through the network
- Identify promptly abnormal peak of claims

10.3 Pilot specification

10.3.1 Legacy Systems

10.3.1.1 Overview

Legacy system name 1			SAP HANA
Type			ERP System
Details	*APIs*		
	Data	*Description*	Sales of Spare Parts to Customers/Distributors/Service Partners Transfer of Spare Parts from Central Warehouse to Regional Warehouse / Technicians
		Format	ABAP Tables
Big Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralised
	Volume (size)		30 GB/year
	Velocity (e.g. real time)		Real Time Sales / Stock Transfers execution

	Variety (multiple datasets, mashup)	Multiple Data Source Tables
	Variability (rate of change)	Real-Time maintenance from 35 different NSO + External Systems
Other Big Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*	Robust and Accurate
	Visualization	-
	Data Analytics	-

Legacy system name 2			Factory Production Quality System
Type			SQL Server
Details	*APIs*		
	Data	*Description*	• Statistical Tests • Functional Tests • Laboratory Tests from 18 manufacturing Plants
		Format	SQL Tables
Big Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Distributed (Each factory has its own Quality system where details about Quality process are stored)
	Volume (size)		30 GB / year per Plant 200 working day / year 150 MB / day per plant
	Velocity (e.g. real time)		Functional test 1 registration for each cycle time : (20 sec) Statistical test 1 registration for each product : (5 min) Laboratory test 1 registration for each product : (days)
	Variety (multiple datasets, mashup)		Multiple Data Source Tables
	Variability (rate of change)		for our purpose a Daily change meet our requirement

Other Big Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*		Accurate
	Visualization		-
	Data Analytics		-

Legacy system name 3			Service Orders and Service Orders Confirmations
Type			SAP BW
Details	*APIs*		
	Data	*Description*	• Service Orders (Call Centers) • Service Orders Confirmations (Technicians) from 35 National Sales Organisations
		Format	SQL Tables
Big Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralised
	Volume (size)		10 GB + 1 GB / year
	Velocity (e.g. real time)		Daily Registration
	Variety (multiple datasets, mashup)		Multiple Data Source Tables
	Variability (rate of change)		Daily
Other Big Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*		Accurate
	Visualization		-
	Data Analytics		-

Legacy system name 4			ADMIN SERVICE.NET
Type			
Details	*APIs*		
	Data	*Description*	• Spare Parts Master Data (more than 350.000 codes)

			• Service Bill of Materials (for more than 120.000 different appliances) • Product Supersessions
		Format	SQL Tables
Big Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralised
	Volume (size)		30 GB data base and 104 GB file system. Growth rate of more than 10% per year.
	Velocity (e.g. real time)		Manual / Daily
	Variety (multiple datasets, mashup)		Multiple Data Source Tables
	Variability (rate of change)		Daily
Other Big Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*		Accurate, Possibility of duplication due to Integration of different companies.
	Visualization		-
	Data Analytics		-

Legacy system name 5			IoT – Smart Connected Appliances
Type			
Details	*APIs*		
	Data	*Description*	• Mainly usage data coming from the cycle of the washing machine when active / no sensor
		Format	Jason
Big Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralised
	Volume (size)		t.b.d.
	Velocity (e.g. real time)		real time
	Variety (multiple datasets, mashup)		t.b.d.
	Variability (rate of change)		t.b.d.
Other Big Data Science (collection, curation, analysis,	*Veracity (Robustness Issues, semantics)*		Accurate, possibility of data interruption/lost in case of missing Wi-Fi connection at the consumer side.
	Visualization		-

action -if applicable)	*Data Analytics*	-

Legacy system name 6			SAP IBP
Type			Integrated Business Planning
Details	*APIs*		
	Data	*Description*	• Sales of Appliances to Customers/Distributors/Trade Partners/Retailers… • Demand Forecast of the Appliances
		Format	Aggregated Key Figures
Big Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralised
	Volume (size)		Less than 1GB per year
	Velocity (e.g. real time)		Daily / Weekly
	Variety (multiple datasets, mashup)		Multiple Data Source Tables
	Variability (rate of change)		From 35 different NSO + External Systems
Other Big Data Science (collection, curation, analysis, action -if applicable)	*Veracity (Robustness Issues, semantics)*		Robust and Accurate for Sales Demand Forecast is the best estimation of sales for each appliance code
	Visualization		-
	Data Analytics		-

10.3.2 Components and infrastructure

10.3.2.1 Overview

ID	BC-SAS-1
Responsible partner	SAS
Tool name	Spare Part Data Model

Overall Description			It's the Data Model designed to contain spare parts data for generic devices. The goal of the data model is providing data to analytic and forecasting applications
Details	*Functionalities offered*		8. Data Model for generic devices
	Data input	*Description*	• Sensor data from connected devices • Historical Spare Parts sales data • Historical Device sales data • Service Orders • Factory Tests
		Format	CSV
	Data Output	*Description*	• Spare parts sales forecasts • Predictive maintenance
		Format	Database tables
	Integration requirements		IDS Vocabularies
	BDVA mapping		BDVA model mapping: 11. Data Management 12. Data sharing platforms

ID			BC-SAS-2
Responsible partner			SAS
Tool name			Data Management Tools
Overall Description			This tool is used to define the ETL process to load data into the Spare Parts Data Model, to create ABTs from data inside Spare Parts Data model and save results from forecasting processes.
Details	*Functionalities offered*		1. User Interface for ETL process design 2. Modular ETL process design 3. In-Database processing on Big Data Platform
	Data input	*Description*	• Spare parts data from legacy systems • Spare Parts Data Model • Output from Analytical tools
		Format	
	Data Output	*Description*	• Spare parts Data Model • ABTs
		Format	Database tables
	Integration requirements		IDS Vocabularies
	BDVA mapping		BDVA model mapping: 1. Data processing 2. Data Management

ID			BC-SAS-3
Responsible partner			SAS
Tool name			Analytical Tools
Overall Description			This tool is used to effectively model and forecast time series in large scale
Details	*Functionalities offered*		• Large-scale time series analysis and forecasting • Flexible override facility • User Interface for Models design • In-Memory data processing
	Data input	*Description*	• Time-stamped data set • Events • Attributes
		Format	Database tables
	Data Output	*Description*	• Statistical forecast and override • Performance error
		Format	Database tables
	Integration requirements		
	BDVA mapping		BDVA model mapping 1. Data processing 2. Data Analytics

ID			BC-SAS-4
Responsible partner			SAS
Tool name			Reporting Tools
Overall Description			This tool is used to explore data, discover connections and show the final results of the analytical models
Details	*Functionalities offered*		• Interactive Reporting & dashboards • Visual discover • Easy-to-use analytics
	Data input	*Description*	• ABTs • Spare Parts Data Model • Forecast results
		Format	Database tables
		Description	• Visual Analytics Reports / Explorations

	Data Output	*Format*	Reports
	Integration requirements		
	BDVA mapping		1. Data Visualization & user interaction 2. Data processing Data Analytics

10.3.2.2 Detailed description

10.3.2.2.1 Architecture Design

The following picture depict the logical architecture design for WP8:

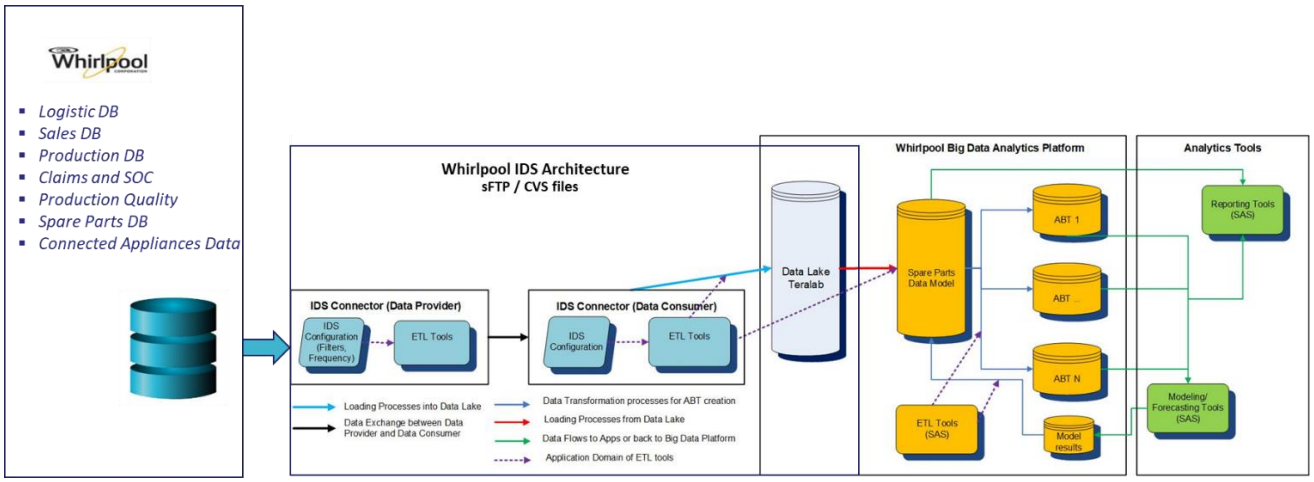

Figure 10-3 WP8 logical architecture design

Architecture is composed by two main blocks:

- Data Ingestion from Whirlpool source data into a Data Lake
- Big Data Analytics Architecture

10.3.2.2.2 Data Ingestion Architecture

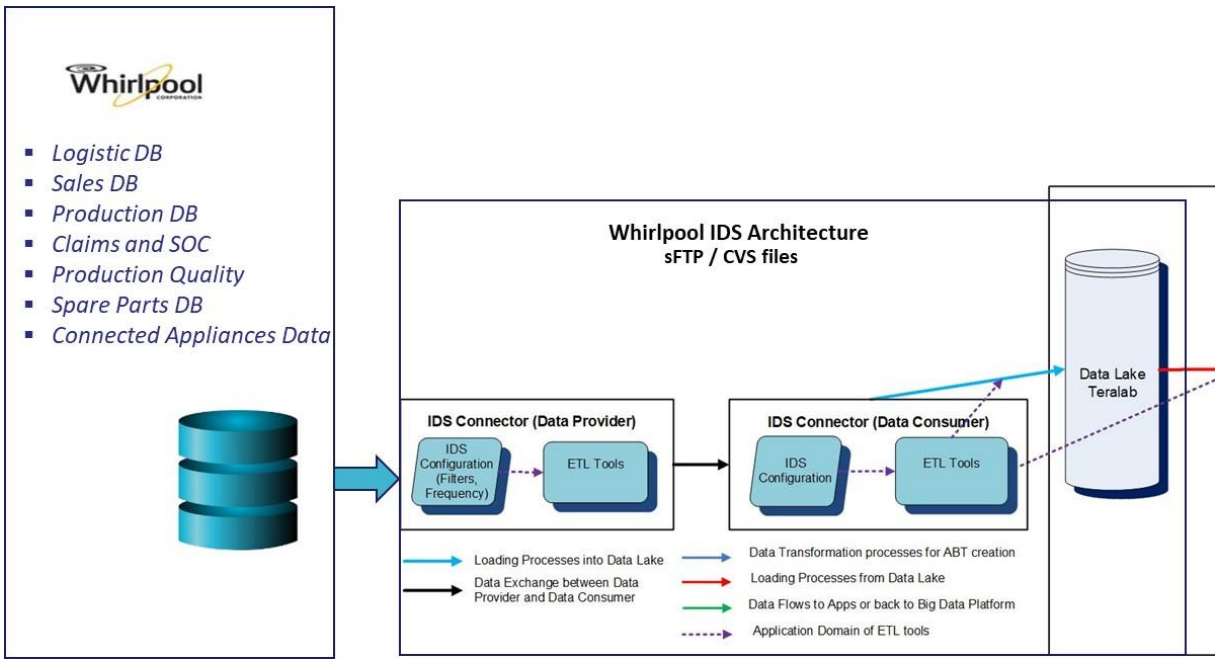

Figure 10-4 Data Ingestion Architecture

Spare parts data are collected by Whirlpool from data sources (legacy systems and private clouds for connected devices) and loaded into a Data Lake in a Big Data Environment. Data are related to:

- Spare Parts Catalogue
- Spare Parts Sales History
- Device Catalog
- Device Sales History
- Connected Devices Data
- Service Orders (with Spare Parts substitution)
- Service Bill of Material (association between Devices and their Spare Parts)
- Device Functional Tests

10.3.2.2.3 Big Data Architecture

Data Lake is the input to the Spare Parts Data Model, which is the source for generating a variety of Analytical Base Tables used for studying, training and execution of predictive models.

Analytical base tables are then loaded into SAS Viya in-memory engine, where analytical tools can perform data analysis on large amount of data in few minutes. In-memory engine is also used for interactive data exploration by end user tools like SAS Visual Analytics.

Access to data, both on Big Data Platform and in memory, will be managed by SAS authorization system.

Results from analytical tools are then loaded back into the Spare Parts Data Model, for historical analysis and model performance evaluation.

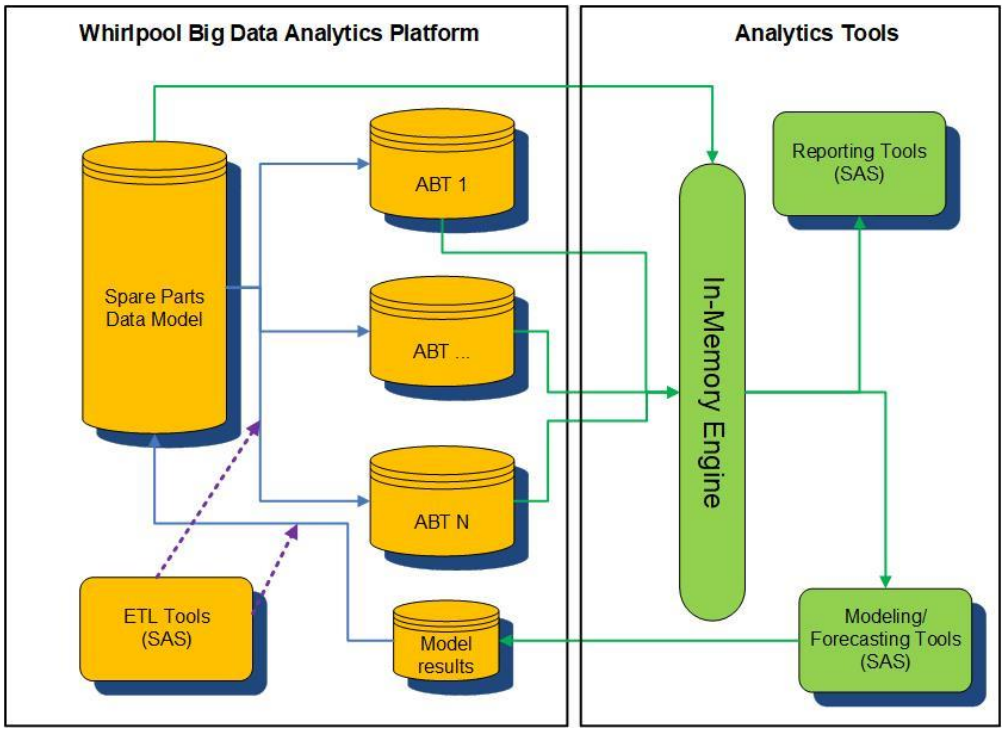

Figure 10-5 historical analysis and model performance evaluation overview

10.3.2.2.4 Interface with Boost Components

The logical schema has been designed according to the architecture requirements of Whirlpool Use Case.

The Big Data Architecture will be developed by SAS and will provide access to data through two main functionalities:

- SAS proprietary visual interfaces
- SAS Rest services to be invoked by third party languages

The data models will be described through Boost ontologies and will contribute to boost vocabularies. Source data descriptions and semantics will be accessible through user interface.

The mapping between WP8 architecture and other components provided by Boost is described in the following picture:

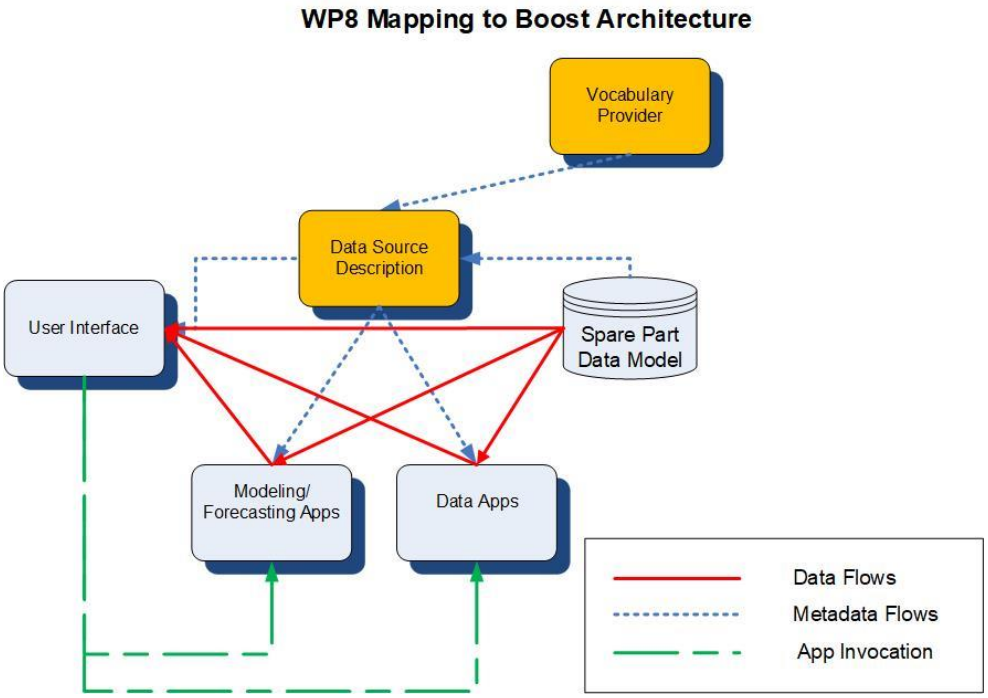

Figure 10-6 Mapping to other Boost4.0 components

SAS interfaces will provide also access to:

- Data Management Apps
  - Apps for data extraction
- Data Processing Apps
  - Apps for data transformation and creation of Analytical Base Tables
- Data Analytics Apps
  - Apps for data forecasting
  - Apps for predictive modelling
  - Apps for interactive data exploration.

10.3.2.2.5 Data Management Tools

Data Management tools provided by SAS consists of:

- A set of database connectors to most of commercial database on the market, including Hadoop distributions (Cloudera, Hortonworks).
- SAS Data Management Languages (BASE SAS, SQL, FedSQL), which provides hundreds of functions for data processing and transformation
- Data Management Applications (Data Integration Studio, Enterprise Guide, etc.), which provides user interfaces for data processing flows generation, without code writing.

In Whirlpool Use Case Data Management tools are used for:

- Extract, transform and load data from Whirlpool Data Lake into Spare Parts Data Model
- Extract, transform and load data from Spare Parts Data Model into Analytical Base Tables used by Analytical and Reporting Tools
- Load results from predictive models into Spare Parts Data Model

SAS DIStudio provide a visual interface to design data integration processes. SAS supports data integration in the following ways:

- Connectivity and metadata. A shared metadata environment provides consistent data definition across all data sources. SAS software enables you to connect to, acquire, store, and write data back to a variety of data stores, streams, applications, and systems on a variety of platforms and in many different environments. For example, you can manage information in Enterprise Resource Planning (ERP) system, relational database management systems (RDBMS), flat files, legacy systems, message queues, and XML.
- Data cleansing and enrichment. Integrated SAS Data Quality software enables you to profile, cleanse, augment, and monitor data to create consistent, reliable information. SAS Data Integration Studio provides a number of transformations and functions that can improve the quality of your data.
- Extraction, transformation, and loading. SAS Data Integration Studio enables you to extract, transform, and load data from across the enterprise to create consistent, accurate information. It provides a point-and-click interface that enables designers to build process flows, quickly identify inputs and outputs, and create business rules in metadata, all of which enable the rapid generation of data warehouses, data marts, and data streams.
- Migration and synchronization. SAS Data Integration Studio enables you to migrate, synchronize, and replicate data among different operational systems and data sources. Data transformations are available for altering, reformatting, and consolidating information.
- Data federation. SAS Data Integration Studio enables you to query and use data across multiple systems without the physical movement of source data. It provides virtual access to database structures, ERP applications, legacy files, text, XML, message queues, and a host of other sources. It enables you to join data across these virtual data sources for real-time access and analysis. The semantic business metadata layer shields business staff from underlying data complexity.

SAS data integration projects have a number of advantages over projects that rely heavily on custom code and multiple tools that are not well integrated.

- SAS data integration reduces development time by enabling the rapid generation of data warehouses, data marts, and data streams.
- It controls the costs of data integration by supporting collaboration, code reuse, and common metadata.
- It increases returns on existing IT investments by providing multi-platform scalability and interoperability.
- It creates process flows that are reusable, easily modified, and have embedded data quality processing. The flows are self-documenting and support data lineage analysis.

10.3.3 System requirements

ID	SR-WP8-T2.1-1	
Business requirement reference	Business requirement 1.1	
Overall Description	Create a central database and data model	
Feature	*Introduction & Purpose of feature*	All the relevant data identified inside and outside the organization should contribute to create a complete set of data for the purpose of: 1) generate spare parts forecast 2) help inventory optimization 3) generate optimum supply plan 4) identify through abnormal picks of claims process and quality issues 5) analyse data coming from connectivity in order to discover correlations between usage and defectiveness
	Stimulus Response Sequence	Inputs are data from the following systems: ▪ Factory Production Quality System ▪ Sales and Distribution ▪ Service Orders ▪ Service Technical Documentation ▪ Integrated Business Planning ▪ Smart Connected Appliance. Outputs: ▪ Centralized Spare Parts Data Model ▪ Analytical Base Tables with all the information
	Functional Requirements	▪ Extract all the relevant data from company databases ▪ Analyse the data to clean and consolidate historical demand for forecasting purpose ▪ Consider lifecycle and supersession to create the correct historical time series for each SKU/NSO

External Interface Requirements	*User Interfaces*	Users will access software applications through SAS Viya web portal
	Hardware Interfaces	▪ SAS Data Application will access data on traditional file systems or HDFS file systems
	Software Interfaces	SAS Viya is open to external software (Python, Lua, Java, R), enabling developers to access SAS Viya in-memory engine through REST services calls
	Communications Interfaces	In order to access data efficiently on HDFS, SAS Embedded Process modules must be installed on Hadoop environment
Performance Requirements		After sales services will perform better both in terms of quality and cost efficiency
Other non-functional requirements		

ID	SR-WP8-T2.1-2	
Business requirement reference	Business requirement 2.1	
Overall Description	Predict in a more accurate way (compared to today) the demand request of spares parts	
Feature	*Introduction & Purpose of feature*	All the relevant data identified inside and outside the organization should contribute to a new way of generating the demand forecast of spares parts in Whirlpool
	Stimulus Response Sequence	Inputs are: ▪ Historical series on spare parts and device sales ▪ Functional and statistical tests on devices ▪ CRM data on maintenance service Outputs: ▪ Forecast models ▪ Report with forecast results and performance error
	Functional Requirements	▪ Read from the central data base the relevant information ▪ Analyse the data to clean and consolidate historical demand for forecasting purpose ▪ Consider lifecycle and supersession to create the correct historical time series for each SKU/NSO

		▪ Consider seasonality where present ▪ Choose the best appropriate statistical model for each SKU ▪ Generate short and medium-long term forecasting per each SKU/NSO (to be then consolidated by warehouse) ▪ Extract statistical forecast to be further used in S099+ supply plan generation ▪ Calculate Forecast Error per each SKU
External Interface Requirements	*User Interfaces*	Users will access software applications through SAS Viya web portal
	Hardware Interfaces	▪ SAS Data Application will access data on traditional file systems or HDFS file systems ▪ SAS Analytical applications are executed in an in-memory engine
	Software Interfaces	SAS Viya is open to external software (Python, Lua, Java, R), enabling developers to access SAS Viya in-memory engine through REST services calls.
	Communications Interfaces	In order to access data efficiently on HDFS, SAS Embedded Process modules must be installed on Hadoop environment
Performance Requirements		Supply Plan vs factory and suppliers will be more accurate due to a more accurate input. Human errors and effort for manual review should decrease.
Other non-functional requirements		

ID		**SR-WP8-T2.1-5**
Business requirement reference		Business requirement 5.1
Overall Description		Use the data coming from connected appliance to initiate a predictive maintenance process on smart appliances
Feature	*Introduction & Purpose of feature*	Though a better understanding of the connected appliances data the process to predict the defectiveness of a specific appliance could be initiated and the information could be used for different purposes:

		1) ensure spare parts procurement and distribution to the right service partners on time 2) alert technicians and service partners on potential problems to be prepared for immediate resolution 3) feedback factory and product development about quality issues
	Stimulus Response Sequence	Input: ▪ Streaming data from connected appliances ▪ Tolerances from device technical specifications Output: ▪ Alerts from In-Streaming Analytical Engine ▪ SAS Visual Analytics Reports
	Functional Requirements	▪ Use data coming from smart appliances and match with service order confirmations ▪ Recognise patters and defectiveness correlations ▪ Alert and Reporting Tool to be used by all the involved impacted function to analyse the results and take decisions ▪ Identify spare parts needed to fix the defect in order to plan it though the network
External Interface Requirements	*User Interfaces*	Users will access software applications through SAS Viya web portal
	Hardware Interfaces	▪ SAS Analytical applications are executed in an in-memory engine
	Software Interfaces	SAS ESP provides API to implement adapters to any streaming flow of data, using C++ or Java.
	Communications Interfaces	SAS ESP will access streaming data on Whirlpool cloud, through a standard or custom adapter (TBD)
Performance Requirements		Accelerate the Defectiveness Patters Recognition and feedback versus the factory and process.
Other non-functional requirements		-

ID	SR-WP8-T2.1-6
Business requirement reference	Business requirement 6.1

Overall Description		Feedback on Abnormal pick of claims and/or identified defectiveness
Feature	*Introduction & Purpose of feature*	Feedback to Factory and/or Markets on Abnormal pick of claims and/or identified defectiveness
	Stimulus Response Sequence	Inputs: ▪ Forecasts Results ▪ Analytical Base Tables Outputs: ▪ SAS Visual Analytics Reports / Explorations
	Functional Requirements	▪ Identify Promptly abnormal pick of claims
External Interface Requirements	*User Interfaces*	Users will access reports and Data Explorations through SAS VA web interface
	Hardware Interfaces	SAS VA needs data to be loaded in SAS Viya in-memory engine
	Software Interfaces	N/A
	Communications Interfaces	N/A
Performance Requirements		React and Reduce promptly the planning and quality issue during the appliance production
Other non-functional requirements		

10.3.4 Design decisions

10.3.4.1 Major design decisions

Table 10-3 Major design decisions in trial 9

ID	Description	Justification	Relevant system requirements
1	External IDS Connector	In Whirlpool use case there are no participants who could act as Data Consumer. Data are exchanged only among Whirlpool departments,	

		so only an internal IDS Connector will be developed	
2	Broker Provider	Due to the absence of a Data Consumer, no Broker Provider (intended as a service to share metadata in an IDS network) is needed	
3	Access to data	Access to data will be managed through SAS authorization technology. SAS provides features to profile access to data, together with functionalities for encrypting data while in motion	
4	Access to platform	Access to the platform will be managed through Whirlpool Active Directory systems or analogue systems	
5	Software Development	All software components will be developed with SAS technology. SAS development tools provide all functionalities to satisfy Whirlpool use case requirements	

10.3.4.2 Components used in pilot

Table 10-4 Components used in trial 9

Component ID	Component Name	System Requirement References	Comments
BC-SAS-1	Spare Part Data Model	BR1.1, BR2.1	
BC-SAS-2	Data Management Tools	BR1.1, BR5.1	
BC-SAS-3	Analytical Tools	BR1.1, BR2.1, BR5.1, BR6.1	

BR1.1 Create a central database and data model
BR2.1 Predict in a more accurate way (compared to today) the demand request of spares parts
BR5.1 Use the data coming from connected appliance to initiate a predictive maintenance process on smart white goods
BR6.1 Feedback on Abnormal pick of claims and/or identified defectiveness

11 Trial 10: Benteler predictive factory 4.0

The section consists of two main parts and provides details for trial 10:

- **Pilot overview**

Provides explanations about the manufacturing processes and plants involved in the trial. Additionally, it explains the objectives to be achieved and the partners involved.

- **Business requirements**

This section provides an overview of the business processes involved in the trial.

- **Pilot specification**

Details the technical specifications required in order to realize the solution for each trial. This includes descriptions of legacy systems to be integrated, software components, and software requirements.

11.1 Pilot overview

11.1.1 General description

The pilot will implement a set of interconnected processes for Smart Maintenance and Services to boost productivity, reduce cost, and enhance quality. This includes:

- Condition monitoring of production machinery
- Prediction of plant failures based on data-driven models trained on historic big data and operate on real-time data streams.
- Fault diagnostics and prescriptive analytics based on data-driven models trained and operating on historic big data for assisting maintenance actions in case of plant failures by matching fault patterns and inferring proper maintenance actions.
- Concept and evaluation for integrated resource planning of spare parts and human resources for maintenance process optimization by interconnecting manufacturing execution, maintenance, and personnel availability data.

For BOOST, Benteler's factory "An der Talle" is in focus. An der Talle is Benteler's largest component production site with the highest turnover. At An der Talle, automotive chassis und structure components are produced by highly automated production lines. The factory's infrastructure entails equipment for joining, hot and cold forming, more than 500

robots, as well as special equipment for milling and laser cutting. Additionally, An der Talle is a center for innovation in automation within Benteler Automotive, targeting intelligent connection and collaboration of humans and machines. The infrastructure also includes connected plants, big data infrastructure and data lakes for condition monitoring of production plants.

An der Talle in detail:

The history Talle plant began classically with the laying of the foundation stone in November 56. The manufacturing plant stared out as a plant for various products made of steel and iron, for example we were very active in pole and boiler construction at the beginning. Over time, however, the Talle developed rapidly and, thanks to motivated and committed employees, became the linchpin of automotive technology. As a result, we continue to set standards for our customers in terms of quality and delivery reliability as the highest-revenue component plant. Our focus is now on the production of chassis and structural components for the automotive industry.

A deep understanding of materials, design and processes is the basis of our success. This enables us to meet today's customer needs comprehensively and satisfactorily. Everything is manufactured locally on the valley - from the pressed part to the finished axle - from the blank to the complete B-pillar. The plant thus serves the entire value chain. Strong and reliable ancillary operations ensure stable and smooth operations even in turbulent times. In the past as well as today we distinguish ourselves through the use of innovative technologies. The first robot was used in 1975 in the Talle. In the meantime, every 10th of the 5400 robots used by BENTELER worldwide in automotive technology are located at Talle. The world's first thermoforming line was also put into operation on the Talle and testifies to the process and innovation leadership of the plant. To ensure safety and lightweight construction in vehicles, we are working on the further development of this key technology. Under the motto "Talle4Future" we are setting the course for a successful future. The topic "Industry 4.0" is very important to us in this context. Both the cooperation between human and machine and the improved provision of information will help us to reduce or avoid downtimes. We will thus continue to make a valuable contribution to competitiveness. Currently about 1150 employees, some of them second and third generation, have made the location what it is today with their knowledge and their willingness to perform. Well-trained employees are a guarantee for a successful company, which is why we are involved in cooperation with universities, research institutions and organizations in OWL. We maintain various cooperations with the University of Paderborn and thus establish contact with potential interested parties at an early stage. We offer a corporate culture characterized by courage, performance and respect.

At the same time, the topic of training and further education is very important to us. Since 1991, 580 trainees, re-trainees and combined students have been taken on at the Talle plant after their training/studies.

BENTELER AUTOMOTIVE PLANT PROFILES

TALLE PLANT PROFILE

BENTELER makes it happen

GENERAL INFORMATION

Established / acquired	1956
Location	An der Talle 27-31, 33102 Paderborn, Germany
Area size (all facilities)	Total size 239,700 sq. m. Plant size 57,000 sq. m.
Employees	Approx. 1,200
Core competencies & technologies	Forming Welding Machining Surface coating Assembly Heat treatment Inspection technologies
Customer awards (since 2011)	General Motors "GM Quality Excellence Award" 2013; "Volvo Cars Quality Excellence (VQE)" award 2014
Certificates	ISO/TS 16949 and ISO 9001 ISO 14001 / ISO 18001 / ISO 50001

"The plant manufactures **chassis and structural components** for numerous OEM. The technological core competencies are **joining, cold and hot forming**. Furthermore, the plant develops new processes and technologies."

Figure 11-1 Talle Plant profile

11.1.2 Objectives

Corrective maintenance strategies lead to costly unplanned downtime of industrial assets. Preventive predetermined maintenance strategies, on the other hand, may result in the replacement of fully functional parts. Moreover, root cause analysis in case of machine failure is a bottleneck in the maintenance process. Careful analysis is required to return assets back to production, but field engineers and service teams often lack data and insights needed to troubleshoot the underlying issues. Data-driven maintenance support and predictive condition-based maintenance strategies are an appropriate means to address these issues.

Continuous machine data processing means continuous analysis, risk assessment, and process coordination resulting in fewer field service calls, remote monitoring and diagnostics, and proactive (predictive and prescriptive) equipment maintenance. This allows major cost benefits by reducing unexpected equipment failure, reducing machine downtime and reducing replacement cost to the most necessary.

While the data-driven modelling techniques for predictive maintenance applications is maturing, these models and their output require careful integration into the entire infrastructure, maintenance organization and process. The conception, selection, training and deployment of data-driven models for different assets is still a manual process, which prevents large-scale rollout of data-driven maintenance schemes. A flexible and interoperable framework, tool-chain and process is missing to boost the impact of data-driven, predictive and prescriptive maintenance appliance.

The objective is to establish and roll out a predictive maintenance framework at the Benteler factory in Paderborn, based on a standardized process covering: data acquisition for reference plants, data-driven modeling, model deployment, model transfer to compatible plants (transfer learning), and the integration into the maintenance organization. This leads to a vision of an intuitive, integrated tool for monitoring of machine conditions (machine health index) and planning of actions.

In summary, this will create the following benefits:

- **Increased productivity**
- **Cost-benefits:** reduction of unexpected equipment failure, reduction of machine-downtime, only replacing expensive parts when they really need to be replaced
- **Enhancement of quality:** stable operation of machinery leads to less production variation and thus improves quality management
- **Safety:** Predictive maintenance would allow potential problems to be fixed before failure occurs, which would create safer operation conditions for operators.
- **Increased competitiveness:** potential cost benefits resulting and improved quality makes the planned maintenance framework a major technical and economical competitive advantage.
- **Improvement of maintenance labor:** Predictive maintenance leads to more controllable maintenance processes, less ad-hoc maintenance and emergency repairs. Maintenance work can thus be better scheduled.
- **Increased labor security:** Better plannable maintenance work combined with increased competitiveness and reduced cost leads to more secure jobs in maintenance.

11.1.3 Participants

You can find an extended description for each of the participant in APPENDIX 1: Participant description

Table 11-1 Trial 10 participants

BENTELER makes it happen	BENTELER BENTELER Automotive supports almost all major vehicle manufacturers worldwide with development, production and services.	Main partner of the pilot.
Fraunhofer IEM	FRAUNHOFER IEM The Fraunhofer Institute for Mechatronic Systems Design IEM is an expert for intelligent mechatronics in the context of industry 4.0. Fraunhofer IEM explores innovative methods and tools for the development of intelligent products, production systems and services.	Will contribute with the research of standard processes and methods for developing and managing Data Science projects, as well as experience in implementing and deploying data science solutions in enterprises
ATLANTIS ENGINEERING	ATLANTIS ENGINEERING is an SME with a long-standing experience in offering services and bespoke products to the manufacturing industry, with emphasis on the decision support for the management and optimisation of production activities and assets' life-cycle, and on the streamlining of various maintenance related processes.	Will bring to the project expertise related to automated decision support and recommendations for streamlining maintenance activities and synchronizing maintenance with production

11.2 Business requirements

This section specifies the business requirements that the solution that will be implemented in this pilot must meet:

- Detect imminent machine failures
- Detect degradation of the machine status, and predict the moment and cause of failure

- Intuitive, easy to understand user interface
- Reduced effort for use and implementation
- Model transfer, between similar machines and model scaling, to smaller or larger factories

11.3 Pilot specification

This section details the technical specifications required in order to realize the solution for trial 10. The section is organized in three sub-sections:

- **Legacy systems**

This sub-section provides an overview of existing data sources in the factory such as databases, sensors, etc. These sources will provide the data for the solution that address the trial's business requirements.

- **Components and infrastructure**

This sub-section provides an overview of the components that make up the solution for trial 10.

- **System requirements**

This sub-section provides an overview of the features required to address the business requirements of trial 10.

- **Design decisions**

This sub-section details design decisions that affect the development of the solution for trial 10.

11.3.1 Legacy Systems

The paragraph consists of a series of tables detailing the legacy systems involved in the solution for trial 10. The description includes relevant APIs, data formats, etc. along with details relevant to big data such as data volume, velocity etc.

Table 11-2 Machine PLC

Legacy system name	Machine PLC
Type	Machine Data (Sensor measurements and PLC signals)

Details	*APIs*		Collection at shop-floor level via standard automation protocols (e. g. OPC/UA)
	Data	*Description*	Sensor measurements and PLC signals, e. g. physical quantities, process values, controller set points, logical signals for PLC and machine state. PLCs should not be accessed directly from big data algorithms, but via Machine Data DB (see further system descriptions)
		Format	Binary format
Big Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Distributed data sources
	Volume (size)		Medium volume, live data from production (Multiplied by the number of machines available --> high volume in total)
	Velocity (e. g. real time)		Near-real-time for most maintenance applications (1 data point per second; available several seconds after acquisition)
	Variety (multiple datasets, mashup)		High variety due to multitude of data sources
	Variability (rate of change)		Medium to low variability. Underlying production processes are repeating and stable, resulting in periodic data with low variability between intervals.
Other Big Data Science (collection, curation, analysis, action - if applicable)	*Veracity (Robustness Issues, semantics)*		High veracity due to machine-oriented measurement. Noise and outliers possible for some measurements, depending on sensor characteristics.
	Visualization		Visualization of selected signals at shop-floor level via HMIs
	Data Analytics		Not applicable

Table 11-3 Machine Data DB for a Hot Forming Line

Legacy system name	Machine Data DB for a Hot Forming Line

Type	Time Series Data Base (InfluxDB)		
Details	*APIs*		HTTP-based/JSON
	Data	*Description*	Time Series Data Base including machine data (sensor measurements and PLC signals, e. g. physical quantities, process values, controller set points, logical signals for PLC and machine state)
		Format	Results from database request returned as JSON
Big Data Characteristics (if applicable)	*Data Source (distributed/centralized)*		Centralized database as a single-point-of-access to data from multiple sources at field level
	Volume (size)		High volume, includes historic data and current data
	Velocity (e. g. real time)		Near-real-time for most maintenance applications (1 data point per second; available several seconds after acquisition)
	Variety (multiple datasets, mashup)		High variety due to multitude of data sources
	Variability (rate of change)		Medium to low variability. Underlying production processes are repeating and stable, resulting in periodic data with low variability between intervals.
Other Big Data Science (collection, curation, analysis, action - if applicable)	*Veracity (Robustness Issues, semantics)*		High veracity due to machine-oriented measurement. Noise and outliers possible for some measurements, depending on sensor characteristics.
	Visualization		Visualization of queries (i. e. selection of time frame and measurements) via customizable dashboards
	Data Analytics		Not applicable

11.3.2Components and infrastructure

The paragraph consists of a series of tables detailing the components in the solution for trial 10. The description covers functionalities, data input/output, data formats, and integration needs of the components.

Table 11-4 Fault Detection Tool

ID	IEM-ATL-DTCN

Responsible partner	Fraunhofer IEM, ATLANTIS		
Tool name	Fault Detection Tool (FDT)		
Overall Description	Sensor measurements monitoring for threshold violation detection (Fraunhofer IEM - rule-based mechanism) and anomaly detection (ATLANTIS – MCOD[4] algorithm)		
Details	*Functionalities offered*		Data analysis, Threshold Violation Detection, Anomaly Detection
	Data input	*Description*	Machine data (time series)
		Format	ResultSet Object (InfluxDB HTTP response format)
	Data Output	*Description*	Time stamp of detected violation/anomaly
		Format	Time series written in InfluxDB
	Integration requirements		The reporting mechanism must report back to InfluxDB so that the results are available for visualization using the Grafana tool.
	BDVA mapping		Data Visualization (Grafana reports) Data Analytics (Descriptive, Diagnostic) Data Processing (Streaming – Real time) Data Management (Collection, Preparation)

Table 11-5 Fault Prediction Tool

ID	IEM-ATL-PRDCN		
Responsible partner	Fraunhofer IEM, ATLANTIS		
Tool name	Fault Prediction Tool (FPT)		
Overall Description	Sensor measurements monitoring and analysis for fault prediction, classification and regression methods (ATLANTIS and Fraunhofer IEM)		
Details	*Functionalities offered*		Data analysis, Data labelling (for classification), Motif Discovery, Data-Event Mapping, Data Classification, Regression
	Data input	*Description*	Machine data (time series)
		Format	ResultSet Object (InfluxDB HTTP response format)

[4] Georgiadis, D., Kontaki, M., Gounaris, A., Papadopoulos, A. N., Tsichlas, K., & Manolopoulos, Y. (2013). Continuous outlier detection in data streams: an extensible framework and state-of-the-art algorithms. *SIGMOD*.

	Data Output	*Description*	Time stamp of detected violation/anomaly
		Format	Time series written in InfluxDB
	Integration requirements		The reporting mechanism must report back to InfluxDB so that the results are available for visualization using the Grafana tool.
	BDVA mapping		Data Visualization (Grafana reports) Data Analytics (Descriptive, Diagnostic, Predictive) Data Processing (Streaming – Real time, Batch) Data Management (Collection, Preparation)

Table 11-6 DSS - Fusion Mechanism

ID	IEM-ATL-FUSION-DSS		
Responsible partner	ATLANTIS		
Tool name	DSS - Fusion Mechanism		
Overall Description	Combination of the output of multiple fault detection and prediction models.		
Details	*Functionalities offered*		Fusion of multiple detection and predictive models. Combination of multiple model outputs to a single result providing recommended actions where applicable.
	Data input	*Description*	Multiple detection and prediction models output
		Format	T. b. d.
	Data Output	*Description*	Time stamp of detected/predicted fault or recommended action (where applicable)
		Format	T. b. d.
	Integration requirements		T. b. d.
	BDVA mapping		Data Analytics Data Processing (Streaming – Real time) Data Management (Collection, Preparation)

11.3.3 System requirements

The paragraph consists of a series of tables detailing the software requirements in terms of features addressing the business needs of trial 10. The details include, associated business requirements, an overview of the functionality, data input/output, relevant

software requirements of the feature, interfaces, performance and other non-functional requirements.

Table 11-7 Software Requirement SR-WP8-BAT-001

ID		SR-WP8-BAT-001
Business requirement reference		BP1-2_BO1_1, BP1-2_BO1_2
Overall Description		BP1-2_BO1_1: Detect immanent machine failure BP1-2_BO1_2: Detect degredation of machine state The provided solution should encapsulate a fault detection mechanism, to be able to detect an immanent machine failure or degradations in the machine state.
Feature	*Introduction & Purpose of feature*	The fault detection feature will accompany the predictive maintenance feature to offer a more complete maintenance solution to the engineers. The fault detection feature will be used as a backup mechanism for the early detection of a fault, if the predictive maintenance mechanism misses to correctly predict an imminence machine failure.
	Stimulus Response Sequence	The fault detection feature will use as input measurements from sensors installed in the machines in time series form. The output of the tool will be also in time series form and it will be written in a central database.
	Functional Requirements	• Validity checks on the input time series • Threshold violation checks on the input time series (rule-based mechanism) • Anomaly checks on the input time series (outlier detection) • Anomaly reporting
External Interface Requirements	*User Interfaces*	The parametrization of the feature and its output should be integrated to the current Benteler's UI ecosystem.
	Hardware Interfaces	The collected sensor measurements are currently written in a database. The provided solution should be able to communicate with the database with the measurements (read rights) and be able to output its results to a specified table in the separate database (write rights).
	Software Interfaces	n/a
	Communications Interfaces	The provided feature will not directly communicate with any hardware device. The sensor measurements are already available in database. Hence, the only needed communication interface is for the communication of the provided tools with that database.
Performance Requirements		T. b. d.

Other non-functional requirements	Communication safety (ssl verification to the DB communication)

Table 11-8 Software Requirement SR-WP8-BAT-002

ID		SR-WP8-BAT-002
Business requirement reference		BP1-2_BO1_3, BP1-2_BO1_4
Overall Description		BP1-2_BO1_3: Predict probable moment of failure BP1-2_BO1_4: Predict probable cause of failure The provided solution will offer predictive maintenance capabilities. It is important provide estimations on the probable moment of failure an if possible provide more detailed estimations on the exact machinery component that is about to fail.
Feature	*Introduction & Purpose of feature*	Predictive maintenance feature along with the fault detection one will offer a complete smart maintenance solution to the engineers. Utilizing predictive maintenance algorithms, the goal is to provide "early" prediction of prominent failures. The term "early" means to provide predictions in a reasonable time space giving enough time to the maintenance engineers to handle the prominent failure before its actual occurrence.
	Stimulus Response Sequence	The predictive maintenance feature will use as input measurements from sensors installed in the machines in time series form. The output of the tool will be also in time series form and it will be written in a central database.
	Functional Requirements	• Validity checks on the input time series • Prediction of imminent failures • Predictions reporting
External Interface Requirements	*User Interfaces*	The parametrization of the feature and its output should be integrated to the current Benteler's UI ecosystem.
	Hardware Interfaces	The collected sensor measurements are currently written in a database. The provided solution should be able to communicate with the database with the measurements (read rights) and be able to output its results to a specified table in the separate database (write rights).
	Software Interfaces	n/a
	Communications Interfaces	The provided feature will not directly communicate with any hardware device. The sensor measurements are already available in database. Hence, the only needed communication interface is for the communication of the provided tools with that database.
Performance Requirements		T. b. d.

Other non-functional requirements	Communication safety (ssl verification to the DB communication)

Table 11-9 Software Requirement SR-WP8- BAT-003

ID		SR-WP8- BAT-003
Business requirement reference		BP1-2_BO2_1
Overall Description		BP1-2_BO2_1: Intuitive, easy to understand GUI The provided UI of both the fault detection and predictive maintenance solutions should be intuitive and easy to use.
Feature	*Introduction & Purpose of feature*	The UI of the provided solutions should hide in reasonable extend the complexity of the back-end mechanisms, providing an easy to understand and to use interface, to the maintenance engineers. The acceptance of the provided solution will be highly affected by the offered UI. It is important the provided solution to follow the Benteler's UI ecosystem in order to provide a familiar experience to the maintenance engineers.
	Stimulus Response Sequence	The UI will be used for the parametrization of the fault detection and predictive maintenance tools and for the visualization of the results.
	Functional Requirements	• Provide an intuitive and easy to use interface. • Transfer the provided parametrization to the respective fault detection or predictive maintenance solution. • Visualize the results.
External Interface Requirements	*User Interfaces*	T. b. d.
	Hardware Interfaces	No hardware communication applies in this case.
	Software Interfaces	n/a
	Communications Interfaces	The UI should be able to communicate with the fault detection and the predictive maintenance tools and with the database with the results.
Performance Requirements		T. b. d.
Other non-functional requirements		Communication safety (ssl verification to the DB communication)

Table 11-10 Software Requirement SR-WP8- BAT-004

ID	SR-WP8- BAT-004

Business requirement reference	BP1-2_BO2_2	
Overall Description	BP1-2_BO2_2: Reduced effort for use and implementation Software components and trained algorithmic models reuse is important to reduce the implementation effort. The parametrization complexity of the implementations should be hidden from the maintenance engineers in order to provide an easy to use solution.	
Feature	*Introduction & Purpose of feature*	The reuse of software components is important in order to reduce the implementation efforts. The reusable components should be tested in order to reassure their functionality. Open source IDS specification implementations (e. g. FIWARE) can be used as a core structural point to build on top of them or custom implementations. Data-driven modelling techniques for transfer learning will be researched, which further allows the re-utilisation of previously trained models for similar plants or similar machines. This will also decrease development and implementation time for other End users In order to reduce the effort spent in the learning curve of the usage of our proposals it is important to provide an integrated to the Benteler's UI ecosystem solution.
	Stimulus Response Sequence	n/a
	Functional Requirements	• Detection of useful third-party or in-house components that can be integrated to our implementation. • Validity check of the reusable components. • Integration of the components and the implementations as a whole to the Benteler's ecosystem.
External Interface Requirements	*User Interfaces*	T. b. d.
	Hardware Interfaces	No hardware communication applies in this case.
	Software Interfaces	T. b. d.
	Communications Interfaces	T. b. d.
Performance Requirements		T. b. d.
Other non-functional requirements		T. b. d.

Table 11-11 Software Requirement SR-WP8- BAT-005

ID	SR-WP8- BAT-005	
Business requirement reference	BP1-2_BO2_3	
Overall Description	BP1-2_BO2_3: Model transfer (between similar machines) This includes transfer of the trained models on the algorithmic level, but also by means of the underlying development process.	
Feature	*Introduction & Purpose of feature*	A standardized developing process will be designed for the overall implementation of smart maintenance application. This will further decrease implementation time for future scenarios and allows to transfer knowledge and algorithms to similar processes and technical systems.
	Stimulus Response Sequence	Input & output description
	Functional Requirements	• Design and implementation of fault detection and prediction modes. • Training of models. • Model transfer between similar machines.
External Interface Requirements	*User Interfaces*	n/a
	Hardware Interfaces	Hardware characteristics must be taken into consideration for the successful model transfer.
	Software Interfaces	n/a
	Communications Interfaces	n/a
Performance Requirements		The transferred models should have similar behaviour in all their applications in different machines.
Other non-functional requirements		T. b. d.

Table 11-12 Software Requirement SR-WP8- BAT-006

ID	SR-WP8- BAT-006
Business requirement reference	BP1-2_BO2_4

Overall Description	BP1-2_BO2_4: Model scaling (to smaller/larger factories) The goal is to transfer our implementations and trained models from small scale deployments to larger ones including their deployment to more than one factory.	
Feature	*Introduction & Purpose of feature*	The specified models and implementations should be able to handle Big Data, in order to be applicable to large scale deployments. Small scale testing is needed in order to reassure their efficient and effective functionality.
	Stimulus Response Sequence	Trained model in small scale should be transferred to large scale deployments.
	Functional Requirements	• Train models in small scale deployments • Transfer models in large scale deployments.
External Interface Requirements	*User Interfaces*	n/a
	Hardware Interfaces	n/a
	Software Interfaces	n/a
	Communications Interfaces	n/a
Performance Requirements		The transferred models should have similar behaviour in all their applications in different machines.
Other non-functional requirements		T. b. d.

11.3.4 Design decisions

Table 11-13 Major design decisions in Trial 10

ID	Description	Justification	Relevant system requirements
IEM-ATL-DTCN	Fault detection will support the fault prediction approach in order to detect, on an early stage, faults that the predictive mechanism was not able to predict.	The prototype implementation of the rule-based fault detection mechanism from Fraunhofer IEM is coded in Python, while ATLANTIS uses Java for the anomaly detection algorithm. Both the approaches currently support streaming	SR-WP8-BAT-001, SR-WP8-BAT-003-6

		data processing, however for the large-scale deployment, ATLANTIS is also working on a distributed version of the anomaly detection algorithm based on Flink. The output of the fault detection tools is written to an InfluxDB database, which is accessible from the Benteler's Grafana installation.	
IEM-ATL-PRDCN	Predictive maintenance is a core element of the Smart Maintenance process and both Fraunhofer IEM and ATLANTIS are going to provide predictive maintenance solutions to Benteler.	Fraunhofer IEM is using Python for both the data labelling and classification processes. ATLANTIS, for the prototype implementation, which will be deployed in the small-scale experiments, is using R for the regression algorithm (i. e. random forests) and Matlab for the motif detection algorithm (matrix profile). Both the motif detection and the regression algorithms support Big Data analysis. However, the R implementation of the random forests is not appropriate for such scenarios. Hence, for the large-scale experiments possibly a random forests implementation in Spark (coded either in Scala or Python) will be used in combination with the Matlab implementation of the motif detection algorithm.	SR-WP8-BAT-002, SR-WP8-BAT-003-6
IEM-ATL-FUSION	A DSS system will be used to create alerts and/or recommendations of	Currently the ATLANTIS DSS is implemented in C# and .NET core, hence it is available for both Windows and Linux based	SR-WP8-BAT-005, SR-WP8-BAT-006

	maintenance actions and/or diagnostic reports, where applicable. A fusion mechanism will combine the output of multiple detection and prediction models into a single result (creating an ensemble solution), which will be fed into the DSS.	operating systems. The fusion mechanism, which will be implemented in the context of the BOOST4.0 project, would be preferable to be implemented using the same as the DSS technologies.	

Table 11-14 Components used in trial 10

Component ID	Component Name	System Requirement References	Comments
IEM-ALT-DTCN	Fault Detection	SR-WP8-BAT-001, SR-WP8- BAT-003-6	
IEM-ATL-PRDCN	Fault Prediction	SR-WP8- BAT-002, SR-WP8- BAT-003-6	
IEM-ATL-FUSION	DSS – Fusion Mechanism	SR-WP8- BAT-005, SR-WP8- BAT-006	

12 References

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[2] "ETSI NGSI-LD," [Online].

[3] "IDSA," [Online].

[4] "OASIS," [Online].

[5] "XAML," [Online].

[6] A. T. Schreiber and Y. Raimond, "RDF 1.1 Primer," W3C Working Group Note, 2014.

[7] B. Otto, S. Lohmann, S. Steinbuß and A. Teuscher, "IDS Reference Architecture Model," IDSA, Berlin, 2018.

APPENDIX 1: Participant description

Trial 1: Volkswagen Injection Moulding Plant

1.1 Volkswagen

The Volkswagen Group, with its headquarters in Wolfsburg, is one of the world's leading automobile manufacturers and the largest carmaker in Europe. In 2017, Volkswagen was increasing its sales towards 10.7 Mio sold cars, representing the largest number of sold cars for a car manufacturer worldwide.

The Group comprises twelve brands from seven European countries: Volkswagen Passenger Cars, Audi, SEAT, ŠKODA, Bentley, Bugatti, Lamborghini, Porsche, Ducati, Volkswagen Commercial Vehicles, Scania and MAN. Each brand has its own character and operates as an independent entity on the market. The product spectrum ranges from motorcycles to small cars and luxury vehicles. In the commercial vehicle sector, the products include ranges from pick-ups, buses and heavy trucks. The Volkswagen Group is also active in other fields of business, manufacturing large-bore diesel engines for marine and stationary applications, turbochargers and -machinery, special gear units, compressors and chemical reactors. In addition, the Volkswagen Group offers a wide range of financial services, including dealer and customer financing, leasing, banking and insurance activities, and fleet management.

The Group operates 121 production plants in 20 European countries and in further 11 countries in the Americas, Asia and Africa. Every weekday, 610,076 employees worldwide produce nearly 42,000 vehicles, and work in vehicle-related services or other fields of business. The Volkswagen Group sells its vehicles in 153 countries.

With its "TOGETHER – Strategy 2025" future program, the Volkswagen Group is paving the way for the biggest change process in its history: the realignment of one of the best carmakers to become a globally leading provider of sustainable mobility. In order to achieve this, the Group will be transforming its automotive core business and will be launching a further 30-plus fully electric cars by 2025, as well as expanding battery technology and autonomous driving as new core competences. Furthermore, a cross-brand business unit for intelligent mobility solutions is to be established as a second pillar. The strategic investment in on-demand mobility provider Gett was the first step in this direction; over the coming years, further services such as robotaxis, carsharing or transport on-demand will be grouped around this nucleus. The successful transformation requires the Group to place its innovation power on an even broader footing: the Group is

driving forward with digitalization across all brands, areas and functions. At the same time, Volkswagen will rely to a greater extent than before on partnerships, acquisitions and strategic investments. To finance investments in future topics, the Group aims to significantly increase efficiency across all areas, brands and regions.

Besides that, Volkswagen gained already sound experiences and outstanding results in former EU Projects dealing with BigData and industry 4.0 approaches. One of these projects was AutoMat which was coordinated by Volkswagen and whose core intention was to establish a novel and open ecosystem in the form of a cross-border Vehicle Big Data Marketplace that leverages currently unused information gathered from a large amount of vehicles from various brands. Volkswagen is also partner of H2020 project Cross-CPP, a follow-on of AutoMat BigData project, with the intention to extent the AutoMat IT environment and data market place by offering data streams coming from diverse mass products, such as vehicles and smart building automation systems. In addition, Volkswagen Braunschweig was also a partner of the EU project DEMI, targeting to enhance existing product/process design systems with features that will enable engineers to collaboratively design energy efficient and ecologically optimal discrete manufacturing processes, and generate appropriate extended monitoring and decision-making services to support manufacturing installations.

Role in the pilot: VW is the main partner in this pilot. VW will define together with ATB and ESIO the concept of the pilot, specify the requirements upon the ICT solutions, provide data for testing, provide ICT infrastructure needed for the future scenario, implement together with ESI and ATB the future scenario solution, detail test and validate the solutions, as well as carry out, together with ATB and ESI, carry out the measurements of the defined KPIs.

1.2 ESI Group

ESI Group is a world leading innovator in Virtual Prototyping software and services. Specialist in material physics, ESI has developed a unique proficiency in helping industrial manufacturers replace physical prototypes by virtually replicating the fabrication, assembly and testing of products in different environments. ESI solutions help world-leading OEM's and innovative companies in making sure that their products will pass certification tests - before any physical prototype is built. More recently ESI Group has invested heavily in acquiring a few companies and new technologies to enhance its portfolio and to support the industry Digital Transformation and offerings solution covering the entire Product Performance Lifecycle (PPL) based on the Hybrid Digital Twin. The company employs about 1200 high-level specialists worldwide to address the needs of customers in more than 40 countries.

In the present trial, ESI is represented with the following groups:

Casting and & Metallurgy Center of Excellence (CoE), Lausanne (Switzerland), Brno (Czech Republic)

ESI is the provider of the well-known Casting simulation software package ProCAST™. ProCAST™ is finite element based and offer a multi-physic solution that addresses the different aspects of the casting process including flow, solidification, microstructural and mechanical aspects. Role of the Casting & Metallurgy CoE is to provide a technological pipeline via project activity that is supposed to enter in the ProCAST™ product. The CAST & Metallurgy CoE is involved in several public funded project on national level and European level. Another important activity of the CoE is also the customization of ProCAST for specific customers.

The Big Data Analytics Center of Excellence (CoE), Lyon (France)

The technology used during the trial is based on the tool INENDI Inspector which is a big data analytics solution to operate deep investigations of complex and highly dimensional industrial (and simulation) data. INENDI Inspector is an investigation and visualization software dedicated to complex and large technical data. It is used to analyze IT logs as well as large IoT data, sensors data or simulations data. It is usually exploited with dedicated data processing modules to deliver specific anomaly detection, prediction or comparisons (either on the simulation side or the sensors side).

The BDA CoE is currently also involved in the H2020 project LAY2FORM whose objective is to create a new cost-effective multistage manufacturing platform, enabling the efficient integration of unconventional technologies in established composites-based processes (http://www.lay2form-project.eu)

SCILAB Center of Excellence (CoE), Rungis (France)

Distributed under GPL license, SCILAB is free and open source software for numerical computation providing a powerful computing environment for engineering and scientific applications. Initially developed by INRIA in 2003, for Computer-Aided Control System Design (CACSD), SCILAB software has quickly gained in capabilities in new domain such as signal processing, machine learning and optimization. In 2012, the SCILAB Team is incorporated to Scilab-Enterprises start-up structure in order to make SCILAB the worldwide reference for Open source numerical and computational software.

Now integrated into ESI-Group ecosystem since 2017, SCILAB Team members and goal remain the same. The SCILAB Team is composed of senior development engineers in charge of the platforms maintenance and enhancement (SCILAB, XCOS, SCILAB Cloud,

ATOMS); a Center of Excellence (CoE) composed of engineers with a strong background in applied mathematics and naturally control system; and recently joined, the founder and maintainer of Octave GNU.

Role in the Pilot: ESI, as the technological provider, will provide the ICT solutions for the big data analytics and simulation in the pilot. They will contribute to the definition of the pilot concept and requirements, specify in detail the SW solutions and implement necessary updates/adjustments of the SW tools to meet the pilot requirements, support implementation of the pilot at VW, support testing of the solution and optimise the ICT solution based on the feedback from VW, support KPI definition and measurement.

1.3 ATB

ATB is an application-oriented research institute founded jointly by the Free Hanseatic City of Bremen and several leading industrial enterprises in Bremen area in 1991. ATB is a part of the long-term strategy of the Free Hanseatic City of Bremen to sustain economy in northern Germany and, particularly, in Bremen by strengthening innovation potentials of industrial enterprises and other organisations. ATB is a highly innovative and efficient technology centre providing system technology related services to a wide spectrum of enterprises and organisations, thereby increasing their ability to remain competitive. ATB has developed into a dynamically expanding research institute operating successfully on the national, European and world-wide market and offering to partners a high level of expertise in several technological domains.

ATB offers services in process/product innovation activities based on advanced information and communication technology solutions. In the VW pilot, ATB is specifically aiming at the development of a technical architecture and supporting the realisation of an integrated solution that will facilitate the aggregation of data and generation of required knowledge. It is also foreseen to combine its expertise and involvement in other big data related projects to elaborate on the synergies with respect to an integrated usage of manufacturing, optimisation and smart product related data as well as analysing the potentials to create an access to data marketplaces for aiming at a circular product life-cycle data interchange.

ATB brings into BOOST 4.0 already experiences from related research projects as.

- AutoMat [H2020-ICT-15-2014-644657] – Automotive Big Data Marketplace for Innovative Cross-sectorial Vehicle Data Services. Core intention of AutoMat (coordinated by Volkswagen) was to establish a novel and open ecosystem in the form of a cross-border Vehicle Big Data Marketplace that leverages currently unused information gathered from a large amount of vehicles from various brands.

- SAFIRE [H2020-FOF-2016 723634] - Develop cloud-based analytics and reconfiguration capabilities that extend the operating systems of smart factories. The SAFIRE solution is targeted as an add-on for existing production systems, or next generation smart factory operating systems, allowing production systems to be transformed to include capabilities for dynamic real-time reconfiguration and optimisation. Therefore, SAFIRE is developing innovative technologies and infrastructure that enable Reconfiguration-as-a-Service for dynamic smart factory systems and manufactured smart products.
- TYPHON [H2020-ICT-2017-1-780251] - Polyglot and Hybrid Persistence Architectures for Big Data Analytics. The aim of TYPHON is to provide a methodology and an integrated technical offering for designing, developing, querying and evolving scalable architectures for persistence, analytics and monitoring of large volumes of hybrid (relational, graph-based, document-based, natural language etc.) data. In this context, ATB and Volkswagen are working together in TYPHON, to develop an opportunity to make collected vehicle and company data consistent and comparable. This is important for making the data accessible and usable for all services within the Volkswagen group.
- DEMI [FP7-ICT-2009-4-247831] - Product and Process Design for Aml Supported Energy Efficient Manufacturing Installations. ATB and Volkswagen Braunschweig was also a partner of the EU project DEMI, targeting to enhance existing product/process design systems with features that will enable engineers to collaboratively design energy efficient and ecologically optimal discrete manufacturing processes, and generate appropriate extended monitoring and decision making services to support manufacturing installations
- CROSS-CPP [H2020-ICT-2017-1-780167] - Ecosystem for Services based on integrated Cross-sectorial Data Streams from multiple Cyber Physical Products and Open Data Sources. The H2020 project Cross-CPP is a follow-on of the Big Data project AutoMat, with the intention to extent the AutoMat IT environment and data market place by offering data streams coming from diverse mass products, such as vehicles and smart building automation systems.

Role in the Pilot: ATB, as applied research Institute, will support VW and ESI in the definition of the plot concept and specification of requirements, will together with VW select the data to be used for big data analytics, will support definitions of the ICT infrastructure and data models, support implementation of the pilot ICT solutions (support implementation/update of the Assistance system), take part in the testing of the implemented future scenario and provide feedback needed for optimisation of solution, support VW and ESI in the definition and measurement/assessment of KPIs.

Trial 2: FILL Gurten

2.1 FILL Gesellschaft m.b.H

FILL, founded in 1966, is one of the world's leading ideas manufacturers for production systems in the fields of automotive, aerospace, sports, energy, wood & construction. The products include machinery and equipment in the fields of aluminium foundry technology, metal cutting, woodworking and plastics or composite / fibre composite automation. Since 1997 FILL is ISO 9001 certified.

Since 2007, FILL has been intensively active in the area of product-accompanying software applications and services. The focus is on additional applications for machine data acquisition and productivity optimization.

Key project staff members in the planned project are:

- Alois Wiesinger: Project Management Product Development
- Stefan Murauer: software development
- Matthias Grimmer: software development
- Michael Schneiderbauer: mechanical and mechatronics engineering
- Patrick Huber: mechanical engineering
- Harald Sehrschön: Head of R&D

The implementation of a digital strategy in machine and plant development has been a central focus of work for many years, ranging from virtual commissioning and data technology production monitoring to automated condition monitoring solutions in the service area. For example, the "Machine Work Flow" system enables a flexibly connected data interface to FILL and third-party systems, the COMMITTO Production Package an intelligent overall solution for recording and evaluating production data and the "Efficiency Control Cockpit" a machine analysis tool to achieve high production reliability in the production process. In connection with modern database, infrastructure and communication systems, the goal is to achieve self-organization through intelligent and networked machines and means of production (cyber-physical system, Internet of Things), as they were addressed in the research project "Digital System" founded by the Austrian Research Promotion Agency (FFG).

FILL occupies a key role in process automation and data organization for complex manufacturing facilities and has the necessary human resources and infrastructure to implement automated production lines. The project-specific priorities are the data

technology preparation of own machines, the development of IT infrastructure and the provision of machine and production data from linked process flows.
Based on experience in customer projects and developed software applications ("Efficiency Control Cockpit", "Machine Work Flow"), precise solutions with high flexibility in data acquisition, data storage and data provision can be realized.

With more than 85 software engineers as well as state-of-the-art workstation equipment, FILL has the necessary resources to professionally handle such projects. FILL has extensive experience in data management of customer and research projects.

The technologies used include not only PC software development and control programming (SCL .NET, C ++, etc.) but also WEB services (eg JSON, XML), communication protocols (eg OPC DA, OPC UA) and many others

2.2 TTTech Computertechnik AG (TTTech):

TTTech Computertechnik AG, founded in 1998 as a spin-off from the TU Vienna, employs ca. 500 employees in the area of robust networked safety controls. Its solutions and best-in-class products improve the safety and reliability of networked computer systems and are used in various critical industries such as automotive, railway, avionics, space, energy production and industrial automation. TTTech's products help deploy dependable networks and real-time controls more efficiently with shorter time-to-market due to re-use of proven architecture and ease of system integration with reduced cost. Its Deterministic Ethernet solutions further support highly scalable and modular open real-time communication architectures, fulfilling all relevant industry standards as well as current safety requirements.

Deterministic Ethernet is at the core of TTTech's activities in several domains. TTTech's Deterministic Ethernet technology, initiated from its TTEthernet core platform. The technology and products enable customers to comply with the highest safety and reliability standards – all over a standard-based Ethernet network. One pf TTTech's research priorities is in matching the flexibility from dependable, real-time communication for the future manufacturing units and large safety-critical systems. The technology and products in the area of Cyber Physical Production units include fog computing hardware devices such as machine and rack mounted fog nodes, as well as a software platform for industrial application hosting, machine control, device management, etc.

TTTech has fundamental know-how in the development of safety-critical architectures and systems. Staff employed at the company has driven the development of TTP, TTEthernet, Deterministic Ethernet and Time-Sensitive Networking (TSN) from the beginning and hold more than hundred patents covering different aspects of the real-time networking

technology related to e. g. clock synchronization, redundancy management and scheduling in time-triggered systems. TTTech is permanently active in further development and standardization of TTEthernet and TSN (SAE Standard AS6802, voting member in IEEE 802.1 and 802.3 working group) and co-develops TSN testbed with the Industrial Internet Consortium.

Main activities in the project/pilot:

TTTech will be involved in the FILL Pilot, where it will bring in its fog node architecture as backbone capable of communicating the required data for enabling big data analysis. TTTech will closely cooperate with the partners in the pilot line (i. e. RISC, Visual Components), other pilots (i. e. VW), and in the consortium and support the integration of the fog node technology into the existing pilot line at FILL and into other pilot installations. Additionally, TTTech will further develop its fog node technology as a multi-purpose IoT device for factory automation, by enhancing various functions like PLC control, condition monitoring, deployment and reconfiguration, as well as interoperability. Finally, TTTech will aim to acquire experience in specific business requirements needed for factory/machine automation in the context of production system, with a focus on real-time requirements on the targeted industrial environments.

2.3 Visual Components

Visual Components is recognized as a global leader in the manufacturing simulation industry and trusted technology partner to many of the leading brands in industrial automation. Founded in 1999 by a Finnish-American team of simulation experts, Visual Components started with a humble goal – to make factory design and simulation technology easier to use and more accessible to manufacturing organizations of all sizes. Visual Components, which recently has become part of the KUKA group, is headquartered in Espoo (Finland) and has subsidiaries in Michigan (USA) and Munich (Germany) along with a global network of partners and resellers.

Visual Components offers a 3D factory simulation suite that consists of a set of innovative tools which set the standard for modern simulation. The simulation suite gives machine builders, system integrators, and manufacturers around the world a simple, quick, and highly cost-effective way to build and simulate their total process solutions.

As technology provider, Visual Components contributes with its knowledge and expertise in Factory Simulation and Visualization technologies. Visual Components 3D simulation software will allow creating the virtual scenarios for the Fill pilot and extending the experience to other pilots in the project. Visual Components is also involved in the standardization initiatives related with Industry 4.0, as member of the IEC SC 65E committee

will push the introduction of the standards developed in BOOST 4.0 in the new standardization initiatives of the IEC group.

Visual Components has a demonstrated experience developing 3D manufacturing simulation software and solutions for the industrial automation community. The 3D simulation tools developed and the know how in the factory simulation domain and in automation systems will bring to BOOST an important background to develop digital twins that mirrors the real factory along the entire production life cycle, enhancing quality and reducing errors using big Data. The open interfaces available in the simulation solutions allow to incorporate and extend the latest technologies in interoperability and communication aligned with Industry4.0. This will enhance the reusability of data and the efficiency in the design and implementation of new production facilities.

Visual Components has experience accumulated in relevant projects that will use in this pilot:

- **L4MS. Logistics for Manufacturing Systems.** L4MS will provide complete digitalization solution (Open Platform for Innovations in Logistics [OPIL] + Visual Components®) to enable cost effective deployment of exceptionally small and flexible robotics logistics solutions requiring no infrastructure change, no production downtime and no in-house expertise, while making investment in logistics automation extremely attractive for manufacturing SMEs. The experience acquired in data communication will be used and extended in FILL Pilot.
- **F2Fit –Factory2Fit.** Empowering and participatory adaptation of factory automation to fit for workers. Developing the Factory of the Future by developing solutions to make the factory environment more flexible and adaptable. Despite Smart Factories are characterized by increasing automation, workers are essential in the factory of the future. Factory2Fit will provide the tools for maximizing the capabilities of the worker in the development of the factory of the future. Fill pilot will take advantage of the know-how of this project at the moment of developing more intuitive interfaces to minimize errors when handling with large amount of production data.
- **LIAA – LEAN INTELLIGENT ASSEMBLY AUTOMATION.** LIAA aims to keep assembly jobs in Europe by creating and implementing a framework that enables humans and robots to truly to work together in assembly tasks. Co-working allows the senses and intelligence of the human to be complemented by the strength and endurance of the automation and so obtains the best from each of them, reducing repetitive injuries and costs and enhancing job satisfaction and the average length of time that a worker can continue in the same job. During the engineering and manufacturing phase Fill pilot will make use of the communication interfaces developed.

- **SkillPro - Skill-based Propagation of "Plug & Produce"-Devices in Reconfigurable Production Systems by AML.** Intelligent production machines and 'plug-and-produce' devices for the adaptive system integration of automation equipment, robots and other intelligent machines, peripheral devices, smart sensors and industrial IT systems. The innovative AML communication interfaces developed in SkillPro will be reused and extended during BOOST and the Fill pilot will take advantage during the configuration and runtime operations handling big data.

2.4 RISC Software GmbH

The non-university research institute RISC has been closely connecting mathematics and computer science with practical experience for nearly 25 years and develops individual software solutions for business, medicine and industry in interdisciplinary teams. The content and local proximity to the basic research of the RISC Institute of the Johannes Kepler University Linz enables innovative state-of-the-art algorithms and techniques in the field of data processing, analysis and visual analytics to be put into practice together with medical and industrial partners.

Founded in 1992 by Prof. Bruno Buchberger, RISC Software deals with the core competences of Symbolic Computing, Mathematics and Computer Science in the fields of Logistics Informatics, Applied Scientific Computing, Medical Informatics and the most modern Computing Technologies. This overall strategy is also very much supported and promoted by the owners, the Johannes Kepler University Linz (80%) and the province of Upper Austria (20%), in particular by the anchoring of the non-profit character in the social contract. With an operating performance of approx. 4.5 million euros and about 60 employees, RISC Software GmbH is also economically one of the successful independent research institutions in Austria.

Through many years of experience with subject areas, such as dynamic infrastructures, processing and analysis of large volumes of data and development of new innovative technologies in the field of machine learning, RISC has implemented numerous projects focusing on big data management with both national and international innovative research partners and companies. This is recognized by international research partners, see e. g. EU projects PLATO-N and PRACE, as well as clients such as Shell, EADS, RHI, Magna, voestalpine, WFL, ILL, DS Automotion, Salinen Austria, TRUMPF and ÖBB.

RISC Software specializes in data collection and processing frameworks that collect, process, and analyse data, with forecasting and data stream simulation an important component. The research and application of neural networks, fuzzy algorithms and machine learning methods has been a tradition at the RISC Institute since 1995, especially

in the context of formal methods, system identification and learning. In particular, the topic of machine learning in combination with Big Data technologies has become an important focus in recent years, both in international research projects (eg EU project MrSymBioMath www.mrsymbiomath.eu) as well as in the field of (corporate) industrial research (eg in cooperation with Shell, Mondi or ÖBB). Further information can be found on the homepage of RISC Software GmbH (www.risc-software.at).

Key project employees in the planned project are listed in alphabetical order. Dominic Girardi, Roxana-Maria Holom, Robert Keber, Stefanie Kritzinger.

Trial 3: VWAE real-time self-learning virtual factory 4.0

3.1 Volkswagen Autoeuropa

Volkswagen Autoeuropa belongs to an automotive manufacturing industry located in Portugal (Palmela) since 1995 and a production plant of Volkswagen Group. It manufactures the Sharan and T-Roc models for Volkswagen and the Alhambra for SEAT, another brand of the Volkswagen Group. Volkswagen Autoeuropa plays a strategic role in the Portuguese automotive industry, as it is the largest automotive manufacturing facility in the country and is responsible for around 10% of all Portuguese exportations. The plant employs around 6000 workers and, indirectly, it employs close to 8000 people through the more than 800 suppliers that provide materials, components and parts to the facility.

The factory covers an area of 2 million square meters: 900,000 square meters are factory premises and 1,100,000 square meters belong to the industrial park. In 2017, Volkswagen Autoeuropa focused on launching a new product - the T-Roc, and a new work system that will lead to a significant increase in production volumes.

The plant covers the entire automotive creation chain from the press shop, body shop, paint shop to assembly. With the introduction of the T-Roc, a Bicolour line has been built that offers 29 different colour combinations and also offers 600 possible combinations of roof, exterior and cockpit finishes. The Toolmaking Business Unit within the Industrial Park employs 189 people and produces tools for the Group. The factory also produces parts for other brands of the Volkswagen Group, which in 2017 had a business volume of 17.2 million euros.

Volkswagen Autoeuropa is one of Europe's most modern automotive production facilities. It was designed using advanced technology and continuously incorporates the latest

developments in automation and computerized production control, in order to meet the high standards required for manufacturing a quality product.

3.2 UNINOVA

UNINOVA - INSTITUTO DE DESENVOLVIMENTO DE NOVAS TECNOLOGIAS (UNINOVA) is a multidisciplinary, independent, and non-profit research institute employing around 180 persons, located in the metropolitan area of Lisbon. It was formed in 1986 by the Faculty of S&T of the University Nova de Lisboa (FCT-UNL - www.fct.unl.pt), a group of industrial associations, a financial holding, and up to 30 companies. It is an active partner of Madan Parque (www.madanparque.pt), a business facilitator and accelerator, incubating Micro and SME's through several layers of support to entrepreneurial activity.

The main aim of UNINOVA is to pursue excellence in scientific research, technical development, advanced training and education. By working closely with industry and universities, technological innovations are transferred into profitable business concepts and existing products further developed to match new industrial requirements. Due to its tight connection with the University and Madan Parque, UNINOVA has, since its foundation, hosted and supported the development of several PhD thesis, as well as the creation of several successful spin-offs. The institute is strongly committed to eEurope and to Lisbon Strategy being involved in many activities that support/enable the developments and actions towards the knowledge economy. GRIS has managed and participated in many national and international research programmes (ESPRIT, BRITE, IMS, IST, ICT, NMP, INNOVA etc) with experience in RTD in industrial systems interoperability, future internet enterprise systems, e-learning and e-training activities, and standards-based activities (e. g. ISO TC184/SC4). The group also coordinated the IMS SMART-fm framework creating a community (funStep community) with more than 700 members, and also supported the launch of several spin-off companies using research results.

The impact and results achieved through these activities is both on the academic and scientific community, with papers published in chapters of books, international scientific journals and conferences. These results are also in use by industrial research projects addressing big data, IoT and interoperability topics, and have been source for further scientific and technical innovations towards seamless interoperable environments and Industry 4.0. These include standardisation communities. The work developed resulted in several international awards.

CTS-GRIS is the UNINOVA department that is involved in BOOST4.0, providing expertise in the domain of Big Data interoperability and analytics. Within these domains, some of the technical focus areas which we address are:

- Methods for data collection, cleaning and fusion, supporting integration across transactional systems, operational data stores, BI (Business Intelligence) platforms, MDM (Multi-Dimensional Data Modelling) hubs, the cloud, and other Big Data platforms.
- Distributed data and process mining, predictive analytics and visualization at the service of industrial decision support processes, including the development of data-driven approaches such as linear regression, using historical large datasets.
- Real-time complex event processing over extremely large numbers of high volume streams, as for example the development of anomaly detection mechanisms aiming to find patterns in data streams that do not conform to expected behaviours.

The group has been involved in several projects related with Big Data Interoperability and Analytics, namely:

- BigDataOcean (H2020 - 732310): aiming to capitalize on existing modern technological breakthroughs in the areas of the big data driven economy
- OPTIMUM (H2020 - 636160-2): establish largely scalable architecture for the management and processing of multisource big data
- C2NET (H2020 - 636909): interoperable cloud-enabled tools for supporting the supply network optimization of manufacturing and logistic assets based on collaborative demand, production and delivery plans
- AQUASMART (H2020 - 644715): provision of smart and open Data Analytics as a service
- FITMAN (FP7 - 604674): test and assess the suitability, openness and flexibility of FI-WARE Generic Enablers

3.3 ASTI

ASTI is an international company founded in 1982 in Burgos, Spain, which is involved in engineering and development of made to measure solutions for logistics. ASTI activity goes from the project analysis in material handling and internal logistics to the development, manufacture and starting up of the designed solutions, as well as all the maintenance along the installation life. (www.asti.es).

The developed solutions by ASTI have contributed to achieve significant cost savings as well as significant quality improvements in its customers' supplies, among them there are leading multinational companies from sectors as diverse as food and beverage, aeronautics, automotive, pharmacy, metal wiring, cosmetics, hospital or banking. The auto-guided vehicles (AGV) systems are the core of ASTI solutions. ASTI, European leader in manufacturing this kind of auto-guided vehicles, has developed its own range, to transport

all kind of loads at various heights, with various guiding systems according to the application to automate and in different environments. Another relevant strategic line for ASTI is the internationalization of its activities. Today, from the headquarters in Burgos, projects throughout Europe and USA are being designed and installed. ASTI team is formed by over 80% of engineers and highly qualified technical staff. The key of ASTI success was and still is the ongoing effort on research and development of new technologies. Our philosophy is based on: the investments in R&D today forge our solutions for tomorrow. ASTI is highly committed with the development of the technical talent, with the boost of the new technologies, with the entrepreneurial character and with the generation of employment, wealth and welfare.

ASTI has been involved in several projects related with Robotics and Communication Technologies:

- L4MS (H2020- 767642): The ambition of L4MS (Logistics for Manufacturing SMEs) is to enable inexpensive deployment of small and flexible logistics solutions requiring no infrastructure change, no production downtime and no in-house expertise. The L4MS will deliver an open industrial IoT platform called OPIL (Open Platform for Innovations in Logistics) together with a 3D simulator to completely virtualize the intra-factory logistics automation and drastically accelerate the innovation process in this area.
- 5G-EVE (H2020 – SEP- 210492233): The 5G-EVE end-to-end facility consists of the interconnection of four 5G-site-facilities (France, Spain, Italy, Greece), which have been selected because of their considerable previous work with vertical industries and standardisation bodies, on top of their 5G technology competences. The 5G-EVE facility will enable experiments with: (a) heterogeneous access, including NR, licensed/unlicensed spectrum, advanced spectrum management; (b) Mobile Edge Computing, backhaul, core/service technologies; (c) means for site interworking and multi-site/domain/technology slicing/orchestration.

CoLLaboratE (H2020 -- SEP-210504249): CoLLaboratE will revolutionize the way industrial robots learn to cooperate with human workers for performing new manufacturing tasks, with a special focus on the challenging area of assembly operations. The envisioned system for collaborative assembly will be capable of allocating human and robotic resources for executing the production plan sharing the tasks according to the capabilities of the available actors. The CoLLaboratE project will build upon state-of-the-art methods for teaching the robot assembly tasks using human demonstration, extending them to facilitate genuine human-robot collaboration.

3.4 Visual Components

Visual Components is a simulation and visualization expert that offers a 3D factory simulation platform to build the Factory of the Future. The platform consists on a set of innovative tools which provides to any shareholder involved in the factory creation, machine builders, system integrators and end users, a simple, quick and highly cost-effective way to build and simulate their entire production process solutions.

Visual Components solutions provide several functionalities:

- Easy to use and intuitive UI
- Large amount of pre-existing virtual models, parametric, component modelling.
- CAD import to create any new virtual component
- Layout configuration tools
- Project ready deliverables
- Advance Robotics tools
- Communication interfaces, OPC UA and Web services.
- Open interfaces to interoperate with any other platform

As technology provider, Visual Components contributes with its knowledge and expertise accumulated during more than 20 years in Factory Simulation and Visualization technologies. Visual Components 3D simulation software will allow creating the virtual scenarios for the VWAE pilot and extending the experience to other pilots in the project. Visual Components is also involved in the standardization initiatives related with Industry 4.0, as member of the IEC SC 65E committee will push the introduction of the standards developed in BOOST 4.0 in the new standardization initiatives of the IEC group.

Visual Components has a demonstrated experience developing 3D manufacturing simulation software and solutions for the industrial automation community. The 3D simulation tools developed and the know how in the factory simulation domain and in automation systems will bring to BOOST an important background to develop digital twins that mirrors the real factory along the entire production life cycle, enhancing quality and reducing errors using big Data technologies. The open interfaces available in the simulation solutions allow to incorporate and extend the latest technologies in interoperability and communication aligned with Industry4.0. This will enhance the reusability of data and the efficiency in the design and implementation of new production facilities.

Visual Components has experience accumulated in relevant projects:

- **L4MS. Logistics for Manufacturing Systems.** L4MS will provide complete digitalization solution (Open Platform for Innovations in Logistics [OPIL] + Visual Components®) to enable cost effective deployment of exceptionally small and flexible robotics logistics solutions requiring no infrastructure change, no production downtime and no in-house expertise, while making investment in logistics automation extremely attractive for manufacturing SMEs. Using OPIL and 3D Simulations, the Application Experiments will conceive highly autonomous, configurable and hybrid (human-robot) logistics solutions driven by the business needs of the manufacturing SMEs.
- **F2Fit –Factory2Fit.** Empowering and participatory adaptation of factory automation to fit for workers. Developing the Factory of the Future by developing solutions to make the factory environment more flexible and adaptable. Despite Smart Factories are characterized by increasing automation, workers are essential in the factory of the future. Factory2Fit will provide the tools for maximizing the capabilities of the worker in the development of the factory of the future.
- **LIAA – LEAN INTELLIGENT ASSEMBLY AUTOMATION.** LIAA aims to keep assembly jobs in Europe by creating and implementing a framework that enables humans and robots to truly to work together in assembly tasks. Co-working allows the senses and intelligence of the human to be complemented by the strength and endurance of the automation and so obtains the best from each of them, reducing repetitive injuries and costs and enhancing job satisfaction and the average length of time that a worker can continue in the same job.
- **SkillPro - Skill-based Propagation of "Plug & Produce"-Devices in Reconfigurable Production Systems by AML.** Intelligent production machines and 'plug-and-produce' devices for the adaptive system integration of automation equipment, robots and other intelligent machines, peripheral devices, smart sensors and industrial IT systems.

3.5 Telefónica I+D

Telefónica I+D (TID) is the innovation company of the Telefónica Group. Founded in 1988, it contributes to the Group's competitiveness and modernity through technological innovation. To achieve this, the company applies new ideas, concepts and practices in addition to developing advanced products and services, It is the largest private R&D centre in Spain regarding activity and resources, and is the most active company in Europe in terms of European research projects in the ICT sector. Over the last few years, within the global market TID has grown to become a network of centres of technological excellence that stretches far beyond the Spanish borders. At the same time, it is working for the companies in the Telefónica Group in the rest of Europe, America and Asia. In addition to

the numerous technical awards it has won since its foundation, the company received the Principe Felipe Award for Business Excellence in 2002.

TID staff has a long experience in new network architectures, infrastructure and services, and is involved in several internal initiatives and collaboration projects related to them. The team also has a long experience in participating and contributing to standards organisations, reflected by the instrumental position played in the creation and the leadership in the ETSI NFV ISG. Finally, our direct connection with a global organization providing Internet services at all levels will ease the collection of knowledge from additional experts, as well as the assessment and evaluation of results in (next-to) real environments.

TID plans to contribute to the research activities of the pilot in two main actions:

- AGV communication improvement, via network data collection, normalization, big data analytics techniques and machine learning algorithms, applied over network traffic information. Using these inputs and techniques, impairments like faults, congestion, traffic loss, delays, etc., will be early detected, and feedback will be provided to the control components of the production environment. The aim is to reduce the impacts in close-to-real-time systems like that of the AGV communication.
- Validation over a 5G network: since at the time of execution of the final pilots it is very likely that 5G is still not widely deployed, TID offers the possibility to test and evaluate the associated solutions and technologies on the 5TONIC lab scenario, where last-generation mobile technology is continuously being evaluated and showcased

Trial 4: +GF+

4.1 +GF+

GF Machining Solutions (GFMS) is the Swiss leading manufacturer of Machine tools for different technologies, Electric Discharge Machining, High Speed Milling and laser texturing devices, and offers also Automation systems and associated software. The group employs some 3200 persons in the world. The Agie Charmilles Unit is the leading manufacturer of electro-discharge (EDM) machines and controls approximately 30 % of the world market-share in value. The Technology Unit Mikron is a leading player in the field of High-Speed Milling (HSM), also mainly used in the mould & die industry, and having a significant penetration in production markets like automotive, aerospace and medical technologies. GFMS comprises also a new unit for manufacturing laser texturing machines,

Agie Charmilles New Technologies, with high potential for the decorative and functional structuring of mould surfaces and in charge of the Industry 4.0 digital solutions for the whole group; STEP-TEC, manufacturer of high-speed spindles, and System 3R, producing automation systems and robots. GFMS has as well as an important Services and Sales Divisions. These products and applications generate annual revenue of nearly 1000 M€ worldwide.

GF has created a Digital Transformation – Industry 4.0 department as of 2016 and a team of 15 engineers specialised in software development and automation are currently setting up dedicated modules for planning, CAD CAM, monitoring, and IIoT analytics solutions for the full machine portfolio of the company. This team coordinates developments at the level of software teams of technical units in charge of each device technology. The company offers now specific CAM and automation execution products as well as a connectivity platform, rConnect, with the company Symmedia, which is part of GF and has over 80 employees fully dedicated to IIoT developments.

GF Machining Solutions has various research and development facilities in Switzerland (Geneva, Losone and Nidau), with various teams skilled in mechanics, electronics, computer science and control systems. These laboratories have the necessary tools for implementing prototype machines, systems, cells, testing them and ensuring their qualification for production phases. An application centre in Geneva has expertise in dedicated application optimisation for the various industries GF MS serves around the world, with antennas in the Americas and Asia. Modern equipment for design, electronic measurement, part accuracy characterisation and surface analysis are also available at these locations.

The relevant products and services supporting the project are:

MPP Software: Multi-Process-Planning software, a modular CAM software for automated creation of NC codes for different technologies (EDM, milling, laser texturing) from CAD designs

E-tracking: Cellular Manufacturing Execution System with adaptive traceability functions for quality control and zero defect manufacturing

Workshop Manager: Automated Execution software for managing hybrid cells with System 3R robots

R-connect: Connectivity hardware and software system for remote control, data acquisition and analysis for all GFMS devices, including a cloud infrastructure for Data Analytics and IoT applications

High Speed Milling, Electric Discharge Machining, Laser Texturing, Automation systems and partnership with EOS for additive manufacturing devices under the GF brand

4.2 Ecole Polytecnique Federale de Lausanne (EPFL)

The Swiss Federal Institute of Technology in Lausanne (EPFL) is one of the two Swiss Institutes of Technology, educating more than 10000 students in all engineering disciplines and participating in numerous national and international research projects in all engineering domains. The group on ICT for Sustainable Manufacturing (ict4sm) of the Institute of Mechanical Engineering of EPFL is involved in various fundamental and applied research projects in the Sustainable Manufacturing domain in collaboration with Swiss and European industrial partners. To respond to the scientific challenges presented by important research problems, the following activities have been defined within ict4sm: Closed-Loop Lifecycle Management, Semantic Modelling and Reasoning for Lifecycle Engineering Applications including predictive maintenance using smart Product Embedded Information devices, methodologies and algorithms for data, information & knowledge transformation etc. Hence, EPFL's ICT for Sustainable Manufacturing (ict4sm) research group will bring to BOOST 4.0 its long expertise in the areas of ICT-enabled sustainable manufacturing, semantics and ontology engineering, information and knowledge transformation, smart cyber physical systems and advanced big data analytics in collaboration with Swiss and European industrial partners and its strong experience from its own research efforts in the framework of relevant projects and research studies.

ICT4SM's mission is to (i) improve the sustainable development of products, (ii) increase the productivity of manufacturing systems and (iii) optimize the operation of product recovery systems. Accordingly, EPFL-ICT4SM has been involved in several research projects funded by the EC and the European industrial partners such as the H2020 projects Z-BRE4K, Z-Fact0r, BOOST4.0, DILECO, bIoTope, FALCON and SatisFactory, the FP7 FoF projects FoFdation, RLW-navigator, IFaCOM, LinkedDesign, PLANTCockpit, the FP7 FoF CSA ActionPlanT, the FP7 NMP project SuPLight, the FP7 ICT project e-SAVE, the FP7 ICT FoF CSA ManuSkills, the FP7 CSA and IMS project IMS 2020, the FP6 and IMS IP project PROMISE, the FP6-NoE project VRL-KCiP, and the FP6 IP projects NEXT and KoBaS.

In BOOST 4.0's +GF+ pilot, EPFL will be responsible for the Development of Big Industrial Data Analytics solutions and predictive models for predictive maintenance and process-product quality modelling (i. e. context-aware algorithms for defect prediction & machine learning algorithms and models for predictive maintenance of assets) based on a semantic framework integrating models and data through an ontology and semantic solution developed in compliance with the new Industrial Ontology Foundry initiative supported by NIST, Airbus, Dassault Systems, Autodesk, US Air Force Research Laboratory and others.

Concerning the Ontology, a prototype for demonstration in an operational environment is developed by EPFL for zero-defect manufacturing in the Z-Fact0r project & for predictive maintenance in the Z-BRE4K project. In BOOST 4.0, these advanced semantic technologies will be further improved and enhanced to support big data analytics in different scenarios.

Regarding the Data analytics module, Context aware algorithms for defect prediction are developed and tested in the Z-Fact0r H2020 project. Besides, machine learning algorithms and models for predictive maintenance are developed in Z-BRE4K H2020 project. In BOOST 4.0, these algorithms and models will be further improved. The technology will be used in +GF+ pilot by design and development of algorithms for prediction of product defects (process related) and machine failures.

EPFL's ICT4SM research group has hands-on experience and holds licences of several semantic tools and platforms, including: (1) A Server running an academic licence of Anzo Enterprise Solution which enables users to link data from multiple Excel spreadsheets and relational databases together in real-time for data collection, collaboration, and reporting; (2) A Server running an instance of the open source OSF (Open Semantic Framework); (3) Several stations running Protégé ontology editor.

4.3 ESI Group

ESI Group is a leading innovator in Virtual Prototyping software and services. Specialist in material physics, ESI has developed a unique proficiency in helping industrial manufacturers replace physical prototypes by virtual prototypes, allowing them to virtually manufacture, assemble, test and pre-certify their future products. Coupled with the latest technologies, Virtual Prototyping is now anchored in the wider concept of the Product Performance Lifecycle™, which addresses the operational performance of a product during its entire lifecycle, from launch to disposal. The creation of a Hybrid Twin™, leveraging simulation, physics and data analytics, enables manufacturers to deliver smarter and connected products, to predict product performance and to anticipate maintenance needs.

ESI solutions help world-leading OEM's and innovative companies in making sure that their products will pass certification tests - before any physical prototype is built - and that new products are competitive in their market space. Virtual Prototyping addresses the emerging need for products to be smart and autonomous and supports industrial manufacturers in their digital transformation.

Today, ESI's customer base spans nearly every industry sector. The company employs about 1200 high-level specialists worldwide to address the needs of customers in more than 40 countries.

In the present trial, ESI is represented by the following teams:

The Big Data Analytics Center of Excellence (CoE), Lyon

The technology used during the trial is based on the tool INENDI Inspector which is a big data analytics solution to operate deep investigations of complex and highly dimensional industrial (and simulation) data. INENDI Inspector is an investigation and visualization software dedicated to complex and large technical data. It is used to analyze IT logs as well as large IoT data, sensors data or simulations data. It is usually exploited with dedicated data processing modules to deliver specific anomaly detection, prediction or comparisons (either on the simulation side or the sensors side).

The BDA CoE is currently also involved in the H2020 project LAY2FORM whose objective is to create a new cost-effective multistage manufacturing platform, enabling the efficient integration of unconventional technologies in established composites-based processes

SCILAB Center of Excellence (CoE), Rungis

Distributed under GPL license, SCILAB is free and open source software for numerical computation providing a powerful computing environment for engineering and scientific applications. Initially developed by INRIA in 2003, for Computer-Aided Control System Design (CACSD), SCILAB software has quickly gained in capabilities in new domain such as signal processing, machine learning and optimization. In 2012, the SCILAB Team is incorporated to Scilab-Enterprises start-up structure in order to make SCILAB the worldwide reference for Open source numerical and computational software.

Now integrated into ESI-Group ecosystem since 2017, SCILAB Team members and goal remain the same. The SCILAB Team is composed of senior development engineers in charge of the platforms maintenance and enhancement (SCILAB, XCOS, SCILAB Cloud, ATOMS); a Center of Excellence (CoE) composed of engineers with a strong background in applied mathematics and naturally control system; and recently joined, the founder and maintainer of Octave GNU.

Trial 5: FIAT autonomous assembly line factory 4.0

5.1 FCA

Fiat Chrysler Automobiles (FCA) designs, engineers, manufactures and sells vehicles and related parts and services, components and production systems worldwide through 159 manufacturing facilities, 87 R&D centres, and dealers and distributors in more than 140 countries.

Its stable of brands includes Abarth, Alfa Romeo, Chrysler, Dodge, Fiat, Fiat Professional, Jeep, Lancia, Ram, Maserati and Mopar, the parts and service brand. The Group's businesses also include Comau (production systems), Magneti Marelli (components) and Teksid (iron and castings).

FCA prides itself in its comprehensive operations approach as the backbone to the organization's worldwide vehicle production, parts and assembly architecture. Innovative technologies and automation are key to overall efficiency and the quality of the final product.

FCA operates 159 manufacturing facilities, excluding joint ventures and including vehicle and light commercial vehicle assembly, powertrain and components plants to build award-winning products on strategically shared platforms. Our streamlined and efficient quality-control processes, along with continuous improvement in supply chain methodologies, are vital to our sustained growth in world-class product offerings.

FCA supports the World Class Manufacturing (WCM) approach, a rigorous and integrated manufacturing system that leverages the involvement and development of our people, throughout all FCA facilities worldwide. It is the foundation not only of our production processes, but first and foremost of our industrial culture.

The target of WCM is to meet the customer expectations by engaging and motivating all levels of our organization. Although technology is important, the investment in our people is what really matters to achieve excellence in our manufacturing system. The core functions of the manufacturing system are outlined in each of the technical pillar methodologies covering safety, cost deployment, focused improvement, autonomous activities, professional maintenance, logistics, quality, early equipment management, early product management, environment and energy. The application of each technical pillar empowers our teams to drive savings and to grow intangible assets. This includes increased autonomy, leadership behaviours and higher knowledge at all levels of the organization.

Our final belief is that to achieve and sustain World Class levels in every aspect of manufacturing, you must develop competent leaders throughout all levels of the organization who are capable of supporting the needs of an ideal production system.

5.2 Prima Industrie

Prima Industrie S.p.A. is a worldwide leader in the field of industrial laser systems and sheet metal working machines. Today the company has about 1800 employees with the headquarter in Italy, where there is the new technological centre of the Group. Prima has also different facilities in the world such as Finland, USA, China and a diffused sales and service network is active in more than 80 countries. Thanks to the two traditional divisions of the group, Prima Industrie is able to work on the main technological aspects of its products. With the machinery division of Prima Power, the company acts on the mechatronics, software, services; with the electronic division, Prima Electro, it focuses on the laser and optics, high power components and numerical control.

The core of the technology Innovation for Prima is represented by three main topics: laser and photonics, Industry 4.0 and advanced manufacturing processes. By working on these core themes, the group boosts the Innovation in its sector.

Thanks to the continuous investment in research and developments and a strong commitment in technology Innovation, Prima Industrie today is also proactive in European research, with different projects and platforms. It is also part of several associations such as EFFRA, EPIC, Manufuture, PHOTONICS21, AM platform.

40 years of experience in mechatronics and photonics have allowed Prima Industrie to be a leading specialist in the world, especially in laser machinery for industrial applications. Basing on this know-how, Prima has boosted even more the research and developments on advanced manufacturing processes.

5.3 Siemens

In this trial, SIEMENS will provide an IoT Operating System (MindSphere), industrial know how and digitalization expertise.

With Siemens global installed base of millions of devices (30 million automation systems, 70 million contracted smart meters, 800 thousand connected products) Siemens can develop high-value applications through MindSphere's application programming interfaces (APIs) and deliver digital services with deep industry knowledge and experience. As a leading global provider of product lifecycle management (PLM) and manufacturing operations management (MOM) software, systems and services with over 15 million licensed seats and more than 140,000 customers worldwide.

The automotive is an innovative and strategic sector, the most dynamic within all the industrial sectors. Siemens is the n.1 technology provider over the automotive sector offering continuously new technology to support the automotive industry over them challenging market.

MindSphere is the cloud-based, open IoT operating system that connects real things to the digital world, and enables powerful industry applications and digital services to drive business success. MindSphere's open Platform as a Service (PaaS) enables a rich partner ecosystem to develop and deliver new applications.

The project will be focused on the following key areas:

- Connectivity
- Collaborating Platform
- Developing domain specific industry applications (and digital services)
- Enabling closed-loop innovation

CONNECTIVITY

Connectivity is one of the main topics in IoT: connecting devices is the first step of any digitalization project. The scope of the project will be provided a standard technology to easily connect AGVs and the other devices involved into the project.

MindSphere allow to connect devices instantly with no programming skills or asset downtimes.

MindConnect Elements (software and hardware) take care of the security mechanism that connect and send data only to the MindSphere Platform.

During the on-boarding process, the MindConnect Elements must go through an authentication process with MindSphere. Once this is done, the two entities agree on cryptographic keys for use in further communications. Thus, the MindSphere Platform is designed to receive data only from valid MindConnect Elements which have successfully completed the authentication procedures during the on-boarding process.

As the level of digitalization increases, so too does the importance of comprehensive security concepts for applications. With defense in depth, Siemens provides a multi-layer concept on security, network security and system integrity as recommended by ISA 99/IEC 62443 and IT Security oriented to industry standard ISO 27001/BSI. The data in motion is always at least 256bit SSL/TLS encrypted.

All communications between the MindConnect Elements and the MindSphere Platform are encrypted via the Transport Layer Security (TLS) 1.2 standard. The TLS configuration is regularly checked to comply with the applicable Siemens Information Security guidelines. This helps in protecting against man-in-the-middle attacks or any manipulation of communication to the MindSphere Platform.

COLLABORATING PLATFORM

MindSphere open platform supports developing applications. MindSphere has several APIs at developers' disposal to enable development of customer owned applications. These APIs are optimized for industrial IoT application development thanks to additional reusable supporting modules (e. g. for visualization, analytics and parsing).

The scope of the platform is to facilitate the implementation of the domain know how (i. e. predictive maintenance algorithms) into a MindApp that can be used by any end user.

DOMAIN SPECIFIC APPLICATION

MindSphere provides a solid foundation for applications and data-based services. Siemens, or any other partner with development skills, will implement an application for the predictive maintenance.

CLOSED-LOOP INNOVATION

Siemens Software and Digital Services enable digitalization of the entire lifecycle, seamlessly integrating product, production and service processes. MindSphere connects to real-world devices and processes, and feeds performance data back into a performance digital twin to drive improved decision making and intelligence.

Trial 6: PHILIPS Autonomous short-batch injection moulding production process

6.1 Philips

Figure 0-1 Philips Drachten Site Overview

Philips was founded in 1891, in Eindhoven, The Netherlands, to manufacture incandescent lamps and other electrical products. For over 125 years, we have been improving people's lives with a steady flow of ground-breaking innovations.

Philips is based in more than 100 countries worldwide and have a truly global vision:

At Philips we strive to make the world healthier and more sustainable through innovation and our goal is to improve the lives of 3 billion people a year by 2025.

Leveraging our expertise and experience in both the clinical space and consumer technologies, Philips is helping healthcare providers, payers, consumers and companies

address the challenges they face – by applying our unique ability to develop and deliver solutions that span the health continuum.

We like to visualize healthcare as a continuum since it suggests the notion of continuous care. And it becomes very compelling when one thinks of this continuum as being *connected*.

We're convinced that in this connected world, it's vital to take a holistic and seamless view of the end-to-end patient journey. At Philips, we are ideally positioned to help consumers on their health journey and to connect them to their caregivers for the right intervention, at the right place, at the right time.

As we address healthcare as a 'connected whole' in this way, we can unlock gains and efficiencies and drive innovations that help improve people's health and enable better outcomes at lower cost.

Figure 0-2 Philips Drachten Products and Processes

Philips Drachten is important for the future of Personal Health, driving key innovations

We develop and produce high-quality innovative, consumer-oriented products for a worldwide market.

These products aim to make life healthier and more comfortable for people. Innovation is more than just developing the product; it also concerns efficient ways to mass-produce these products. Our development departments also guide and steer the operations at production and supply centers across the world.

Philips opened the gates of the Drachten site for the production of shavers in 1950. Many developments have taken place since then. Manual work has largely made way for highly advances automated production methods. This allows us to keep production costs low and stay competitive on a global market.

Philips CL in Drachten (Philips Drachten) develops a wide range of innovative products like rotary shavers, beard trimmers, hairdryers, female epilators, vacuum cleaners, SENSEO® coffeemakers and Wake-up Lights.

For more than 60 years Philips has been manufacturing shaving systems in their factory in Drachten.

Philips Drachten is world leader in the mass production of rotary shaving devices, occupying over 50% market share of a € 1 billion market. Other products developed in Drachten, are made in multiple factories across the globe. Philips Drachten employs 2000 people, including 600 developers with 35 different nationalities.

Philips Drachten manufactures all shaving heads (80 Mio pieces/yr) for the Drachten and Zhuhai facilities, in addition to producing all mid-end and high-end shavers. Low-end shavers are made in Zhuhai. The Drachten factory encompasses a large suite of highly automated processes that are used for metal forming, metal finishing, 1K and 2K plastic injection moulding, lacquering, electronics and assembly. Processes are monitored and controlled by inline measurements and Statistical Process Control.

6.2 Philips Electronics Nederland (Philips Research)

Royal Philips is a diversified health and well-being company, focused on improving people's lives through meaningful innovation in the areas of Healthcare and Consumer Lifestyle. Innovation Philips actively participates in 'Open Innovation' through relationships with academic and industrial partners, as well as via European and regional projects, in order to improve innovation efficiency and share the related financial exposure. In 2016, Philips invested EUR 2.0 billion in Research and Development, or 8.2% of sales. Royal Philips' total IP portfolio currently consists of 79,000 patent rights, 49,000 trademarks, 86,000 design rights and 4,400 domain names. Philips filed 1,690 patents in 2016, with a strong focus on the growth areas in health and well-being.

Philips Electronics Nederland will participate in this proposal via Data Science department from Philips Research. Philips Research has a long heritage of pioneering innovation (inventions related to x-ray, optical recording, CD, DVD, etc.), currently focusing on data driven research and service orientation. Philips Research will contribute to tasks related to data analytics in the use case led by Philips consumer lifestyle on improving existing Injection moulding process performance using big data analytics.

The mission of the Data Science department within Philips research is to lead Philips into the Digital era through world-class innovations on data analytics and digital security. The focus of the department is on advancing the automated analytical methods used to extract

new knowledge from data. The department builds on several interconnected competences including Machine Learning, statistics, probability models, pattern recognition, computer vision, signal processing and data engineering. We use the advances in the aforementioned scientific disciplines, as well as new digital platforms to create innovation for Philips businesses by real-time extraction of insights from various sources like sensors, mobile devices, Web, and social networking sites. Next to that, security and privacy are addressed and taken into account already in the design phase of Philips digital propositions. The department plays a crucial role in digital and data intensive research projects using these competences.

6.3 IMEC

October 2016, the nano-electronics research center, IMEC, and the digital research and incubation center, iMinds, have been merged into a unique high-tech R&D hub under the brand name IMEC. IMEC is a world-leading research and innovation hub in nanoelectronics and digital technologies. By combining our widely acclaimed leadership in microchip technology and profound software and ICT expertise, we drive digital transformation. At IMEC we create groundbreaking hardware and software innovation in application domains such as manufacturing, healthcare, smart cities and mobility, logistics and energy.

One of IMEC's ICT-focused departments is IDLab (http://idlab.technology/), which performs fundamental and applied research on internet technologies and data science. IDLab counts about 300 members (40 professors, 50 post docs, 200 researchers, 15 support staff members). Major research areas are machine learning and data mining, semantic intelligence, distributed intelligence for IoT, cloud and big data infrastructures, multimedia processing, wireless and fixed networking, electromagnetics, RF and high-speed circuits and systems. IDLab has a unique research infrastructure used in numerous national and international collaborations. IDLab collaborates with many universities and research centers worldwide and jointly develops advanced technologies with industry (R&D centers from international companies, Flanders' top innovating large companies and SMEs, as well as numerous high-tech start-ups).

Trial 7: GESTAMP automotive part prescriptive quality assurance factory 4.0

7.1 Gestamp

Gestamp is an international group dedicated to the design, development and manufacture of metal automotive components. The Group specializes in developing innovatively

designed products to achieve increasingly safer and lighter vehicles, thereby reducing energy consumption and environmental impact. Gestamp is in more than 20 countries and has more than 100 plants and 13 R&D centres worldwide.

Gestamp main strategic priority is a high business diversification by region (Linked to the growth plans of clients), customers (With the contribution of global solutions, becoming the benchmark supplier for the world's leading automobile manufacturers) and products (Extended portfolio: Body products, strengthened chassis products and mechanisms).

Technology and leading R&D capabilities

Gestamp perceives innovation as a means of progress, Gestamp's innovation efforts are aimed at weight reduction, improvement in safety, increase in comfort, new technologies and processes and new materials.

Gestamp's commitment to developing innovative, high quality products has defined our approach to our customers. As a global leader in the automotive supplier industry in the use of high strength and ultra-high strength steel, which find their application in many body parts of the car where it helps to reduce vehicle weight and improve fuel and emissions efficiency while also improving safety in a cost-effective way. Many of its products are manufactured using our state-of-the-art technologies in innovative press hardening (Hot stamping common definition) and other high strength stamping processes. Significant investments over the last 3 years in rolling out our PHD and stamping technology in our plants around the world to respond to growing demand from OEMs for products.

Innovative products and market-leading processes are developed through targeted R&D platform, which has a dedicated team of approximately 3,000 employees, across 13 facilities spread around the globe. Underlying innovative products and processes and in-house capabilities is the maintenance of rigorous quality management systems in all of manufacturing plants and R&D facilities.

In developing and rolling out new models, OEMs are increasingly collaborating with suppliers to design models around common platforms and are seeking to consolidate their supplier-base with an increased focus on large, technically and financially strong global suppliers that are capable of producing consistent and high-quality products at competitive prices. As a result, large, multi-technology, high-quality Tier 1 suppliers such as Gestamp, are increasingly taking market share from smaller competitors and fitting these OEM criteria.

Gestamp has strategic and long-standing relationships with main largest OEM customers, which are based on confidence and an understanding established over many years of successful collaboration. Gestamp has proven within years, is capable to deliver solutions to complex projects, truly globally and on a consistent and high-quality basis, across the product portfolio with long-standing relationships with the largest global OEMs consequently.

7.2 Innovalia

Innovalia Association is an independent private Associated Research Lab, recognized as a R&D technology centre by the National Register of Technology Centre based on their R&D services to companies. Innovalia, with more than 25 years of experience in technology-based product and service innovation with SMEs, assists SMEs in the development of ICT-based solutions in the areas of information security, software quality, M2M and mobile multimedia information services. Innovalia products and services address major telecom operators, broadcasters, transport infrastructure operators and manufacturing industries. Innovalia has an international presence, with premises in Spain – Basque Country, Madrid, Catalonia, Canary Island; Europe; Asia, Central and South America. Innovalia Association is a Technology Agent of the Basque Country Innovation Network (Innobasque) and assembles skills, laboratories and resources from its four foundational companies. The Innovalia Association is organised into three different Units: Information & Communication Technologies (ICT) Unit, Nanotechnology and Advanced Metrological Unit, Manufacturing and Knowledge Management Unit.

Innovalia's business activities broadly span the whole European market, the supply of RTD services, the networking of private and public companies with heavy emphasis on SMEs, SME collaboration activities and SME training. Innovalia enjoys a very high level of collaboration with large numbers of companies throughout Spain and the European continent. Among others, the activity sectors where the Innovalia Association focuses its activity includes Aeronautics and Space, Automotive, Electronics & Communications, SME Management, Industrial, Tourism and Entertainment, Metal-mechanics. Innovalia Association is a Future Internet for Manufacturing and FIWARE Steering Board Member, and full member of the European Association for the Factory of the Future (EFFRA), the European Association of Big Data (DBVA) and the European Alliance of the Internet of Things (AIOTI), which reinforces the importance of these key technologies in the Industry 4.0 within the lines of action of the Innovalia Association. Furthermore, Innovalia participates in the key ETPs, PPPs such as NanoFUTURES, MANUFUTURE, EUSPEN, EMVA, Photonics XXI, NetWorld2020, WWRF, ECSEL, ARTEMISA, ITEA and CELTIC.

Innovalia is part of FITMAN Core Consortium (FI-PPP Phase II Use Case project for the manufacturing sector). Innovalia has led the business process requirement elicitation for 10 EU trials, the Digital Factory Platform development, the conception the "FIWARE for Industry Innovation Lab" exploitation instrument and developing the Smart Factory trial at Automotive multinational TRW. Moreover, Innovalia is Director of the Regional Liason of the FML, the Community Group founded as a result of the FITMAN project, which seeks to enable Industry 4.0 through the use of FIWARE technologies.

Moreover, INNO successfully led the CSAs I4MS-Gate (ICT Innovation for Manufacturing SMEs) FoF-PPP (2013-2015) and I4MS-Growth (2015-2018). In both CSAs INNO had a major role in the dissemination of the open calls launched within the 11 projects part of the initiative. Additionally, INNO is core partner of FABulous and part of the technical core consortium within BeinCPPS, performing as a DIH in the Basque country in Spain.

INNO leads the Spanish Competence Centre on Cyber Physical Production Systems, acting as one of the five ecosystems in the selected Smart Specialization Strategy Vanguard regions -Lombardia (IT), Euskadi (ES), Baden-Wuttemberg (DE), Norte (PT) and Rhone Alpes (FR)-, facilitating INNO to be in contact with a large number of competence centres and manufacturing SMEs. Innovalia has also participated in other meaningful projects such as PSYMBIOSYS H2020-FoF project, ProDiGi a Spanish flagship project promoting the use of FI technologies in automotive sector, FP7 Sensing Enterprise project OSMOSE and FP7 ComVantage IP project.

To continue its strong and strategic position in the automotive manufacturing industry, Innovalia has deployed a new facility in the Automotive Intelligence Centre (www.aicenter.eu). The AIC-Automotive Intelligence Centre is a unique value-generation centre for the automotive sector based on a concept of open innovation in which companies improve their competitiveness through cooperation. The AIC-Automotive Intelligence Centre focuses on:

- Integrating all necessary capabilities, at local and international levels.
- Implementing multiple independent, but complementary projects.
- Working with the flexibility to respond to the needs of local companies as well as multinationals and vehicle manufacturers.

7.3 i2cat

i2CAT Foundation is a non-profit research and innovation centre which promotes mission-oriented R+D+i activities on advanced Internet architectures, applications and services. The centre stands up for a new open innovation framework, fostering the collaboration between companies, public administration, the academic environment and end-users.

i2CAT has a wide experience in multiple national and European R+D+i projects, leading research lines in new fixed & mobile network architectures, wireless sensor networks, and content-based multimedia technologies, with the aim to develop new products, services and applications in the fields of eHealth, Smart Cities & Smart Regions, Advanced Manufacturing and Culture/Creativity.

The Open Big Data Technologies Area is focused on fostering the adoption of the data-driven philosophy by the society through leveraging the potential of Big Data technologies. Some of the most important aspects that the area tackles are: scalable architectures for Big Data processing, Open Big Data, and Big Data preparation (curate, clean, enrich, integrate). The main R&I line of the area is data virtualization, a concept that allows tailored access to shared Big Data environments where several users access to the same data sources but that they are so large it is difficult to process them using traditional database and software techniques and moreover, they cannot be moved or replicated.

Innovation to drive ICT research towards market and society needs The Innovation Business Units (IBUs) aim is to boost the collaborations with the innovation ecosystem and at increasing the social and business impact of the research capabilities and the knowledge generated by i2CAT. Focused on verticals, the Innovation Business Units have a deep knowledge of the market (companies, needs, relevant players, users, etc.) in order to figure out innovative solutions based on the expertise and technologies of i2CAT research areas.

i2CAT's Industry 4.0 Innovation Business Unit aims at collaborating with companies in:

- The development and deployment of digital technologies that allow the collection, integration and analysis of all data about operation processes.
- The digitization of products, by adding smart sensors and data analytics tools to generate data on product use and refine products to meet the increasing needs of end-customers.

The expansion of the companies offering by providing disruptive digital solutions like data-driven services and integrated platform solutions

7.4 Eneo

ENEO Tecnología S.L. was created in 2003 as a company specialized on the development and commercialization of products based in Linux Operative System for businesses, as well as the corresponding support services: consultancy, formation, support, etc. Since its origins, ENEO has evolved from a company oriented towards small and medium enterprises to one basically oriented towards big enterprises and public administrations. In 2003, the

company launched "Marte Firewall", a bandwidth monitoring and management system. From then on, further developments were done, adding the original solutions innovative features such as anti-spam, IPS, Filters, etc. ENEO, from the network management side, has a strong activity within the Open Source Community. The company has had a strong activity within the ambit of IDS/IPS systems.

In 2012 ENEO changed its model and opened itself to Open Source under redBorder brand, which actually is using as its commercial brand name, which took to its first Open Source product presented in 2012, redBorder IPS, and which started the complete solution ecosystem of network monitoring and cybersecurity.

Since then ENEO has become a company that develops network data security management software for high performance and trust environments and whose objective is to develop solutions for a highly complex technology market, especially in the consolidation of advanced network infrastructures to make them faster, secure, reliable and easy to manage. In addition, the alliances with market leaders like IBM and Check Point, among others, allows ENEO to offer high compatible and easy to integrate products. ENEO clients comprise public administrations and AENA as big infrastructure manager and other key companies like Santander, BBVA, Telefónica, Euskatel, etc. ENEO it's the national provider of high availability HW solutions for top of line segment and has the technology to offer cybersecurity solutions for critical infrastructures. In collaboration with integrators, ENEO distributes as well its HW solution. ENEO's cybersecurity technology RedBorder has been adopted by CISCO in Palo Alto within its products in its fog computing strategy. RedBorder offer includes the following specific modules aimed at providing industry-leading real-time NTA and cybersecurity:

- **IPS/IDS system (Intrusion):** The intrusion module is a rule-based approach to network security. The system matches network activity to a set of predefined rules which it then uses to alert network managers or directly prevent traffic which meets the established criteria. The main advantage against the current business scenario is that GESTAMP will be able to define specific, customized rules based on the conditions and use cases in the factory. The other components of the security approach will also facilitate the development of additional rules in the future. This will provide a significantly higher degree of protection than solutions which a sold without customization.

- **Network Traffic Analysis (NTA):** This module allows network technicians to monitor the status and activity on the network in real time. This approach is an ideal complement to the rule-based IPS/IDS module as it allows technicians to focus on identifying potential threat activity which is not currently classified. The module

allows technicians to immediately take action when they identify potential threats. This module also provides a general overview of network activity and health, aiding in the identification of potential technical problems not directly related to cybersecurity. The main benefit with regards to the current business process is the ability of technicians to visualize network activity in real time in easy to understand, customizable dashboards.

- **SIEM system (Vault):** This module can analyse and manage a large number of logs, offering the possibility of detecting more complex threats which the IPS system cannot detect. This approach works by analysing historical network data against security events to identify how the event occurred. The vault module offers capabilities such as metadata extraction to normalize data from numerous hardware vendors, data enrichment, correlation, and storage.

ENEO participates in the OpenFuture initiative coordinated by Telefonica (https://www.openfuture.org/) which promotes the entrepreneurship talent worldwide in order to transform innovative ideas into successful businesses. Thanks to this participation, ENEO will be able to open an office in Palo Alto (San Francisco) in 2016. In addition to the partnership with CISCO, ENEO also has partnerships with market leaders such as IBM and Check Point companies. Similarly, ENEO also supports the Open Source technology participating in various events such as the Day OpenExpo flocking to companies around the world to meet the development of new solutions and free software tools.

7.5 Trimek

TRIMEK is one of the main manufacturers of metrological systems and solutions worldwide, and is the leading company in the Basque Country and Spanish markets in the field of Coordinate Measuring Machines (CMM). TRIMEK develops metrological and dimensional inspection solutions for the automotive, aeronautical, ship building, energy, transport and machine tool industrial sectors. TRIMEK holds expertise in the area of coordinate measuring machines, robotics, machine integration, metrological software and control development.

TRIMEK also provides consultancy and services related to dimensional metrology processes and metrology SW platforms. Covering any metrological need that a company might have, from machinery maintenance and calibration, to other services such as measurements in house or reverse engineering. TRIMEK is also working in new applications for their technological background such as iterative processes with AM machinery where accuracy, quality and reverse engineering is a key factor for designers and manufacturers.

Among TRIMEK's products and services we would like to highlight the following: Measurement systems, machines and installations. TRIMEK designs, develops and customizes high precision 3D inline measurement systems, 3D in-process quality control solutions and 3D Coordinate Measuring Machines (CMM). TRIMEK metrological instrumentation provides optimum metrology solutions from the inspection of very large parts, down to high accuracy 3D micro and nano-dimensional feature analysis; M3 Gages. TRIMEK designs, develops and manufactures automated in-line scanning systems for reliable and efficient 3D information acquisition for multiple types of materials – metallic alloys, aluminium, invar, titanium, composites, thermoplastics… M3 Gages can be directly integrated in the measurement process optimization platform M3® (http://www.innovalia-metrology.com/en/) developed and commercialized by TRIMEK; M3 Software. As part of the company M3 Platform, TRIMEK provides highly efficient, secure and flexible virtual part information management solutions for storage of massive 3D point cloud information and high-performance exchange and sharing of virtual part information. M3 is an innovative software for metrological use that enables non-contact and contact measurements; Dimensional metrological services. TRIMEK provides a wide range of services based on verification, calibration and retrofitting of CMMs; training, staff outsourcing, digitalization, reverse engineering, 3D measurements and "in situ" metrology; and Consultancy services: TRIMEK provides consultancy services supporting the customer in the procurement and commissioning of metrological equipment, development of turnkey metrological facilities, design and evaluation of measurement process and analysis on customer parts.

7.6 Capvidia

Capvidia provides application software supporting transition of engineering process to Industry 4.0. Our products provide link between CAD and digital metrology standardizing engineering processes and data exchange. Based on the ANSI QIF standard the digital thread is maintained through product lifecycle from the start in the 3D CAD system to downstream applications such as manufacturing, quality control and archiving. Capvidia is an active developer of the ANSI QIF standard (http://qifstandards.org/) DMSC consortium member. We are also an early adapter of industry standards like ANSI QIF and ISO STEP AP242. Capvidia applications support CAD data interoperability, CAD data quality assessment, CAD data validation and conversion from native CAD into open standard MBD definitions (QIF and STEP AP242).

In BOOST project Capvidia will focus on the support of the QIF standard to link CAD with digital metrology. Our intention is to provide a software platform for effective communication and exchange of the engineering data defining the product (3D CAD model) combined with PMI (Product Manufacturing Information) with downstream processes as

manufacturing and quality control collecting and evaluating information about final product quality. QIF is a standard and a "place holder" for various types of data in structured and standard way defined by the QIF ontology. QIF includes 3D CAD model definition (represented as BREP, triangulation or point cloud) – QIF MBD, measurement plans defining "how" and "what" has to be inspected – QIF-Plans, definition and specification of the measuring equipment to be used QIF-Resources, resulting measurement data collected with help of different metrology equipment (scanners, CMM, gauges, touch probes, etc.), QIF-Results and definition of statistic treatment of the results, QIF-Statistics.

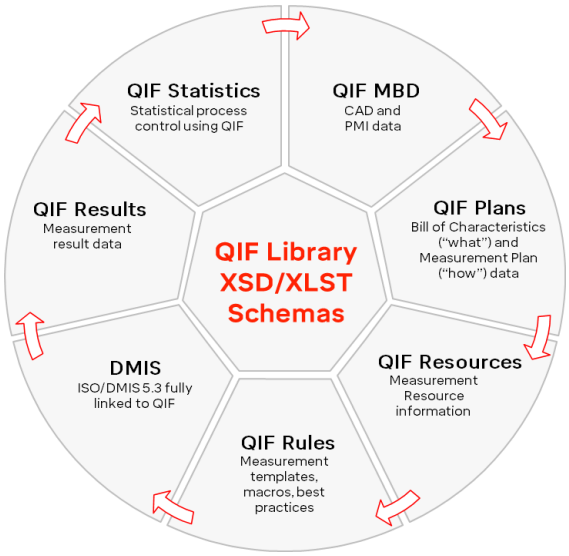

Figure 0-3 QIF Libraries

The QIF data format is open for easy access and integration with other applications (XML implementation) and provides full data traceability by use of the unique QPUID identifiers. By implementing workflows based on the QIF standard the following common industry problems are solved:

- End-to-end workflows possible for verification;
- Data interoperability between stages;
- Traceability issues;
- Reproducibility issues;
- Communicability issues;
- Version control;
- Integration with existing management systems;
- Industrial CAD data with 3D Annotations (PMI) associatively linking tolerance information to design features enables design information to be passed downstream to all other process steps in the chain;

- Intellectual property rights can be controled.

Through BOOST project we intend to demonstrate practical use of the QIF standard and its advantages to effective and smoothly communicate engineering data to support transition to Industry 4.0.

Trial 8: Volvo truck digital assembly factory 4.0

8.1 Volvo Trucks

Since 1927, Volvo has developed from a small local industry to one of the leading suppliers of commercial transport solutions providing products such as trucks, buses, construction equipment, and drive systems for marine and industrial applications. Today, the Volvo Group is one of the world's leading manufacturers within these product segments. The Group also provides complete solutions for financing and service. The Volvo Group, with its headquarters in Gothenburg, employs about 100 000 people, has production facilities in 18 countries and sells its products in more than 190 markets. In 2017 the Volvo Group's net sales amounted to about SEK 335 billion (EUR 35 billion). The Volvo Group is a publicly-held company. Volvo shares are listed on Nasdaq Stockholm.

The Volvo Group comprise ten business areas: Volvo Trucks, UD Trucks, Renault Trucks, Mack Trucks, Group Trucks Asia & JV:s, Volvo Construction Equipment, Volvo Buses, Volvo Penta, Governmental Sales and Volvo Financial Services. Our various operations are organized to deliver the greatest possible focus on customers and their needs and to exploit and harness the Group's far-reaching and shared resources in the best possible way.

Volvo Group has established leading positions on a global market. Based on sales volumes, the Group is the world's second largest manufacturer of heavy-duty trucks, one of the world's largest manufacturers of construction equipment, buses, and heavy-duty diesel engines, as well as a leading supplier of marine and industrial engines.

We also combine the best of two worlds: synergies by having global organizations for product development, manufacturing, and purchasing but still clear leadership and responsibility for each brand to make sure that customer needs are understood throughout the entire organization. In this way, the Group harnesses the full potential of its various brands while creating a clearer profile in its various customer segments.

The Volvo Group builds on 90 years of corporate history defined by value-led innovation. Our commitment to quality and safety is rooted in the visionary approach of our founding fathers, Assar Gabrielsson and Gustaf Larson and their aim to produce safe, high-quality vehicles.

Innovations within transport will reshape the cities of tomorrow. Automated driving, electromobility, and connected vehicles will allow for quieter, cleaner and safer megacities to grow and prosper. For us in the Volvo Group, technology means the aspiration to move forward, constantly working together to improve and do better. It means creative and innovative thinking, evolutionary and revolutionary problem solving - all in order to reach our vision

The Volvo Group's mission is driving prosperity through transport solutions. The Volvo Group's vision is to be the most desired and successful transport solution provider in the world.

8.2 CERTH

CERTH/ITI is one of the leading Institutions of Greece in the fields of Informatics, Telematics, and Telecommunications, with long experience in numerous European and national R&D projects. It is active in a large number of research domains such as Security and Surveillance, Image and Signal Processing, Computer & Cognitive Vision, Human-Computer Interaction, Virtual and Augmented Reality, Multimedia, Database and Information Systems and Social Media Analysis. CERTH/ITI has participated in more than 175 research projects funded by the European Commission (FP5-FP6-FP7 & H2020) and more than 160 research projects funded by Greek National Research Programs.

CERTH-ITI exhibits substantial research on industrial and logistics domains. CERTH-ITI carries a significant expertise on process modeling and the development of simulation platforms and visual analytics for highly complex systems, ontologies, and semantic matching, sensing and signal processing, big data manipulation and forecasting for industry and e-business.

8.3 IBM

Hyperledger Fabric[5] (simply Fabric) provides an open source, industrial-grade implementation of a private blockchain used as the distributed ledger and smart contract engine for BOOST 4.0 (for a comparison between permissioned and permission fewer

[5] https://www.hyperledger.org/projects/fabric

models refer to[6]). Hyperledger is a Linux Foundation charter, founded in Jan, 2016. As per today, has more than 160 members, fastest growing project in Linux Foundation history.

According to a recent survey from Juniper from August 2017[7], IBM was perceived as the leading provider of Blockchain technology in the world with more than 400 engagements. In the BOOST project, partner IBM is responsible for the applicability of Blockchain technology to the project use cases. IBM Israel Science and Technology Limited, better known as IBM Research – Haifa, was first established in 1972. Since then, the lab has conducted decades of research vital to IBM's success. The lab is one of 9 research laboratories located outside of the United States and has close working relationships with IBM Israel and its twin research laboratory in Zurich.

Since FP4, IBM Research – Haifa has participated and led numerous EU-funded projects and is considered an Israeli leader in EU projects participation. The designated group in Haifa has been involved in six EU projects, four FP7 (FIWARE, FIspace, SPEEDD, and FERARI) and two H2020 projects (Psymbiosis and DataBio) in addition to BOOST 4.0.

IBM Research – Haifa is an active contributor to the Hyperledger Fabric open source code.

Trial 9: Whirlpool whitegoods spare part sensing customer service factory 4.0

9.1 Whirlpool

Whirlpool EMEA is the wholly owned European subsidiary of Whirlpool Corporation, the world's leading manufacturer and marketer of home appliances, born in 1911 and based in Benton Harbour (MI- USA), which recorded in 2012 revenues for more than 18 billion dollars and a total of more than 52 million units in more than 130 countries. Whirlpool Corporation is present in the world in 13 countries in 4 continents and is deploying 65 Research & Technology centres, employing approximately 68,000 people.

Whirlpool Europe, Middle East & Africa (EMEA) was born in 1989 with the acquisition of Ignis/Philips, and was traditionally headquartered in Comerio, in the Northern Italian province of Varese, close to Milan.

[6] T. Swanson. Consensus-as-a-service: A brief report on the emergence of permissioned, distributed edger systems. Report, available online, Apr. 2015. URL: http://www.ofnumbers.com/wp-content/uploads/2015/04/Permissioned-distributed-ledgers.pdf.
[7] https://www.juniperresearch.com/resources/infographics/blockchain-enterprise-survey-august-2017

With the recent acquisition of Indesit, in October 2014, it employs approximately 22,000, has a sales presence in more than 30 countries and manufacturing sites in 7 countries.

Whirlpool is now the largest player in the region, with its three pan-European brands, Whirlpool, Indesit and KitchenAid, two regional brands, Hotpoint and Bauknecht, and a number of other local brands, including Scholtes, Ariston, Laden, Polar and Ignis, which reached annual sales of approximately €5 billion in 2015, and around 25 Million products shipped in 140 countries worldwide.

In 2017 the headquarters was moved to Milan (Pero) but the Fabriano location headquarter of the Indesit company was also maintained and it's there where the consumer service department is mainly located.

Here below a representation of where we came from:

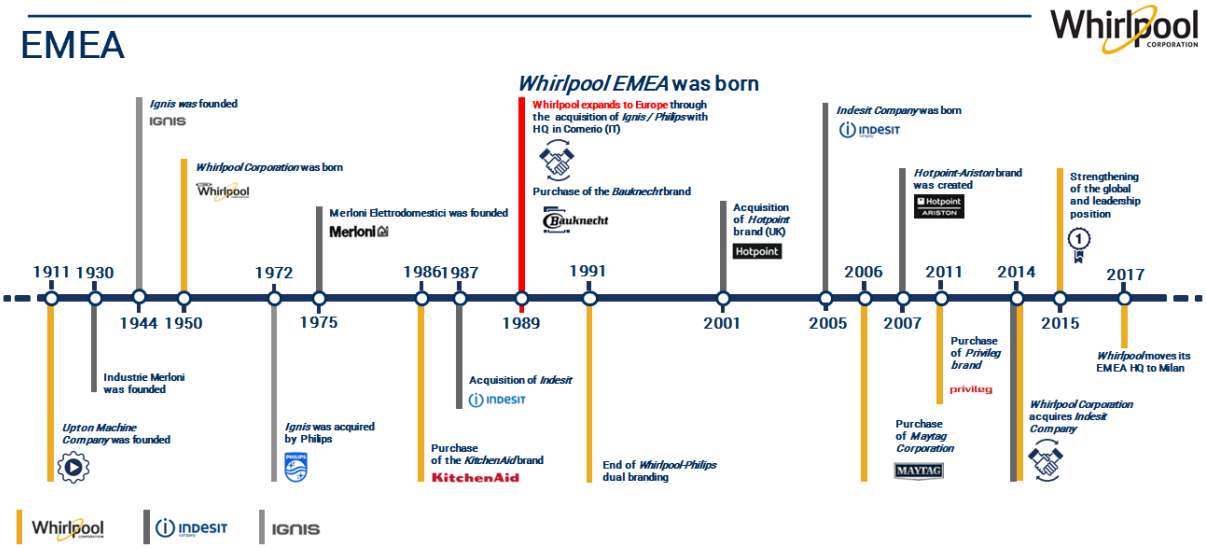

Figure 0-4 Whirlpool history line

The history of the company dates back in the late forties when an Italian entrepreneur, Giovanni Borghi started his small company based in Comerio, Italy, which grew exponentially during the fifties and seventies becoming the Italian leader in white goods. In 1973, the company was acquired by Philips BV becoming part of its Major Domestic Appliance division together with Bauknecht Hausgeraete, a German company. In 1989 Whirlpool Corporation acquired the MDA division from Philips MDA and Whirlpool Europe started its life.

The company followed a period of strong growth during the 90's moving from 2.2B net sales of 1993 to more than 4B in 2008, and it's currently facing the economic crisis which sees a market contraction and a negative impact of raw material cost increase.

However, Whirlpool strongly believes in the power of brands and innovation to break out of an industry stalemate and challenge the market. Since 1989, Whirlpool Europe has invested more than 1.1 billion Euros in the development of its brands and the creation of innovative products that consumers are proud to own. This has proven to be a winning strategy and in just a few short years has allowed Whirlpool to become the number one brand in Europe (1996). Whirlpool invests in innovation as a key strength and distinguishing factor with regard to the competition, placing Whirlpool in the vanguard and offering unique solutions that grant a competitive advantage and encourage consumers to choose Whirlpool products.

The manufacturing in Whirlpool EMEA has always played an important and central role, and due to the high pressure given by strong competition in Europe, the technological and organizational development has been fostered during all the past years. Here below a representation of the main manufacturing sites in EMEA, in Carinaro specifically the new hub for spare parts and accessories was born in 2016 as a result of a full integration of Whirlpool and Indesit service logistic structure:

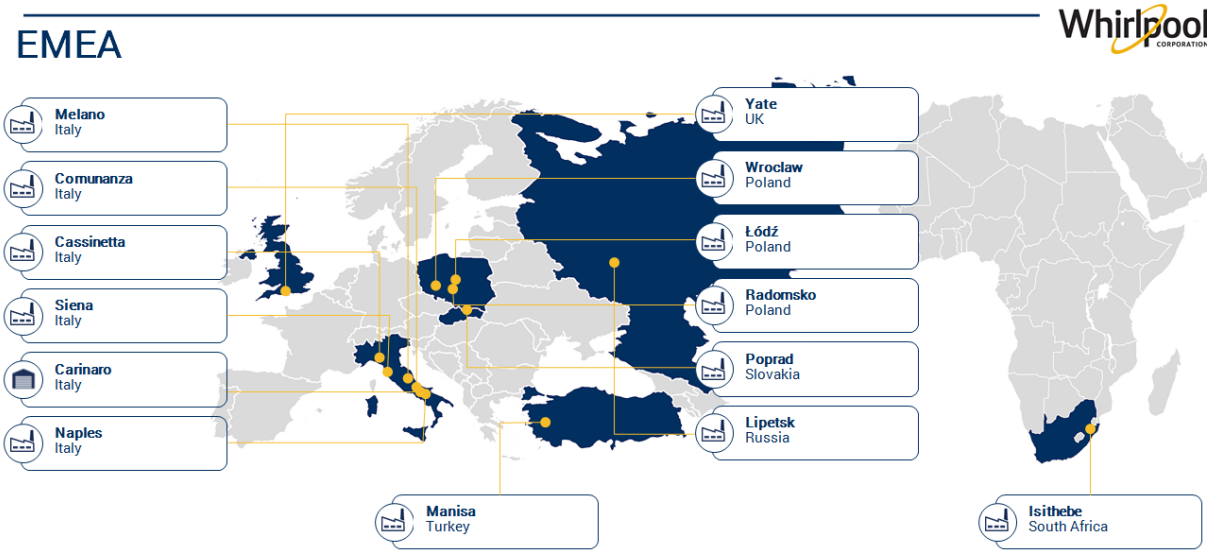

Figure 0-5 Main Manufacturing Sites in EMEA

Figure 0-6 EMEA Countries

The **Consumer Service & Quality Department** inside Whirlpool EMEA is organised as described before by function: Supply Chain and Procurement, Sales and Marketing, Field Service and Quality. Every department do have a specific role and accountability in serving more than 8 million consumers and visit more than 4 million of houses per year.

The supply chain is a key element of the service structure with the goal of serving with the best possible speed and quality the consumers thought to optimisation of the planning processes, operations (freight and warehouse) and customer relations.

As explained in previous paragraphs, the EMEA Consumer Service Logistic network for the distribution of spare parts is organised with a Central Warehouse based in **Carinaro** plus 8 main regional Spare Parts Centres (SPCs) that are serving both service partners and direct technician accordingly to the whirlpool service network set up of the specific country. The product range managed by this logistic network is not only composed by traditional and commercial spare parts but include also accessories and cleaning products (WPRO).

Current economic and technical context for Consumer Service is characterized by the interaction of multiple and different factors concurring in determining a very high overall complexity:

- Spare parts operations are one of the key factors in ensuring favourable service levels for customers. Customers are paying more and more attention to the quality of after-sales services, which directly affect their purchase decisions.

- Spare parts supply chain management is more complicated than that of finished products. The complexity of the parts business is generated by its own unique attributes. The life cycle of spare parts is longer than the one of the appliances and the total number of SKUs is very huge. Additionally, the demand for parts is relatively unstable and difficult to forecast. All of the above pose enormous challenges to parts planning, purchasing, ordering, and logistics, among other operations.

9.2 SAS

SAS is the leader in analytics: it helps organizations turn data – about customers, operations, financials, security and more – into information they can apply to solve day-to-day issues and reach long-term goals.

SAS solutions help battle cybercrime, combat financial and insurance fraud, speed lifesaving drugs to market and zero in on marketing sweet spots. All by organizing, analysing and visualizing data. Across many industries, SAS helps grow customer loyalty, manage and mitigate risk, streamline operations and lower costs.

SAS software is in action at more than 75,000 business, government and university sites in 140 countries. They include 93 of the top 100 companies on the 2014 Fortune Global 500® list. Privately held SAS has seen continuous revenue growth since its founding in 1976.

SAS' success is inexorably tied to its reputation as one of the best places to work in the world. Present in Italy since 1987, the structure counts 330 employees, Offices in Milan, Rome, Venice, Turin and Florence, 39 Universities using SAS and 78 Partners.

Big data and high-performance analytics

Big data. The volume, velocity, variety and complexity of data can overwhelm organizations' storage or compute capacity. Traditional data management and reporting methods no longer can keep up. High-performance analytics from SAS cuts data processing time to a fraction of previous levels. What once took hours or days – calculating financial risk or optimizing pricing for millions of SKUs – now takes minutes or even seconds.

Among SAS' solutions for big data we can mention:

- Data visualization with analytics muscle. SAS Visual Analytics allows users of all skill levels to visually explore data while tapping into SAS' powerful analytics. Industry analysts laud its ability to explore large amounts of data in an instant. Now fortified with SAS Visual Statistics, the offering puts industry-leading analytics tools into the

hands of everyday users, fueling collaboration between business analysts and data scientists

- The Internet of Things and Hadoop. SAS Event Stream Processing analyzes data as it pours in, so organizations can make immediate decisions, SAS Data Loader for Hadoop makes it easier for data scientists to access and prep data without waiting for IT.

Analytics in the cloud

Speed and exceptional accuracy make SAS a perfect match for the demands of cloud computing, which is enabling customers to tap into far more data at lower cost. SAS continues to invest in new cloud offerings, cloud enablement of existing offerings, partnerships with cloud providers, and global expansion of SAS Cloud Analytics. And with growing privacy concerns increasing pressure to keep data local, we are expanding our cloud infrastructure around the world.

SAS & Manufacturing sector

Precise forecasting based on up-to-date, accurate data. Inventory that's balanced with demand in near-real time. Supply plans aligned with demand forecasts. SAS manufacturing skills and solutions include demand-sensing and shaping capabilities for:

- Demand-driven planning: generate accurate forecasts at every level;
- Multiechelon inventory optimization: manage production and logistics to match fluctuating customer needs and changing marketplace dynamics;
- Demand sensing and shaping: translate demand signals – like seasonality, price, promotions, events and merchandising – into a more effective, market-driven response.

9.3 Politecnico di Milano

Politecnico di Milano is the most important technical university in Italy and one of best in Europe, according to recent rankings. Since 1836, Politecnico di Milano has been active in several scientific and technical fields and will join through the Department of Economics, Management and Industrial Engineering (DIG). In particular, the Research Group of Manufacturing is involved in this project with its specific competences in the fields of Manufacturing Strategy, ICT for Manufacturing, Social and Environmental Sustainability in Manufacturing, Product and Service Development, Manufacturing Systems Design, Production and Maintenance Management, Education in Manufacturing in which the Group can be considered the leader among the Italian Universities and Research Centers.

For the Whirlpool case, POLIMI is leading T8.1 Pilot Set-up, Cognitive Industry 4.0 Service Design & Data Preparation and Task 8.4 Pilot Area KPI Collection and Benchmarking Data as well as contributing to Task 8.2.1 Whirlpool Experimentation and Task 8.3.1 Whirlpool Large Scale & On-site Trials.

In T8.1 POLIMI will refine and adopt its methodology for Requirements Engineering and Business Process Modelling (evolution of GRAI Method), replicating it to the BENTELER case.

In T8.2 and T8.3 POLIMI is in charge of the alignment between the WHR technical Architectures with the Reference Architecture of WP2 and with the development tasks in WP3.

- In T8.4 POLIMI will refine and extend its methodology for KPIs Engineering (evolution of ECOGRAI Method) as well as creating bridges to Business Benchmarking methods (Databench project), replicating it to the BENTELER case.

Trial 10: Benteler predictive factory 4.0

10.1 BENTELER

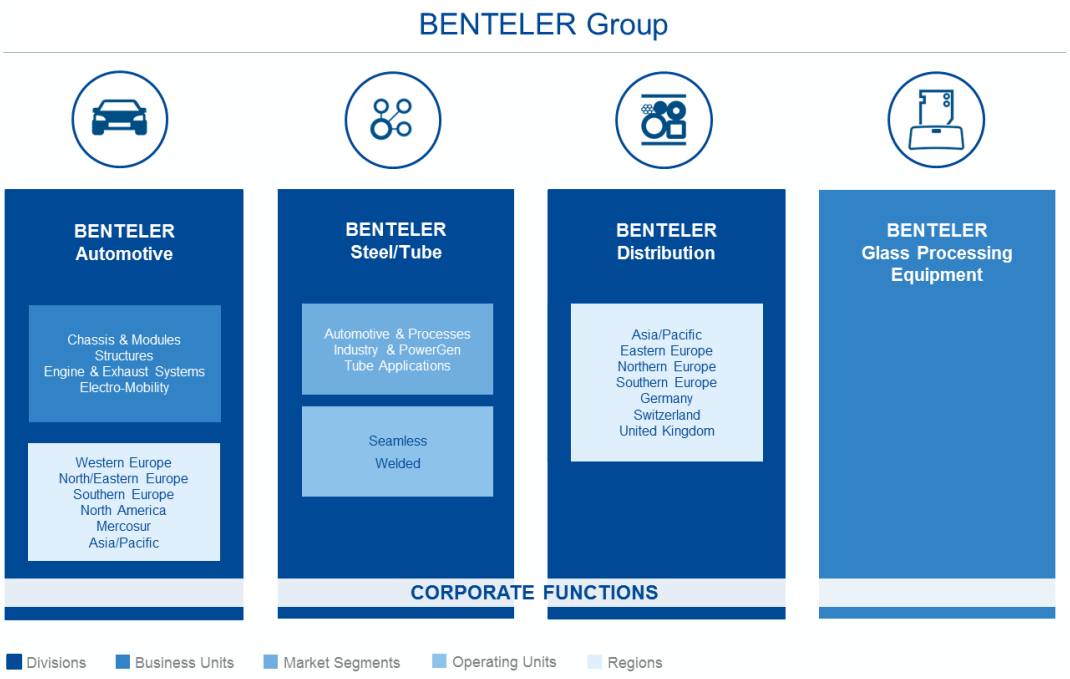

Figure 0-7 Benteler Group Structure

The three divisions BENTELER Automotive, BENTELER Steel/Tube and BENTELER Distribution are organized under the umbrella of the strategic management holding BENTELER International AG based in Salzburg, Austria. Technologically excellent and strong in

implementation, the company develops solutions that make a difference - for customers, employees and society.

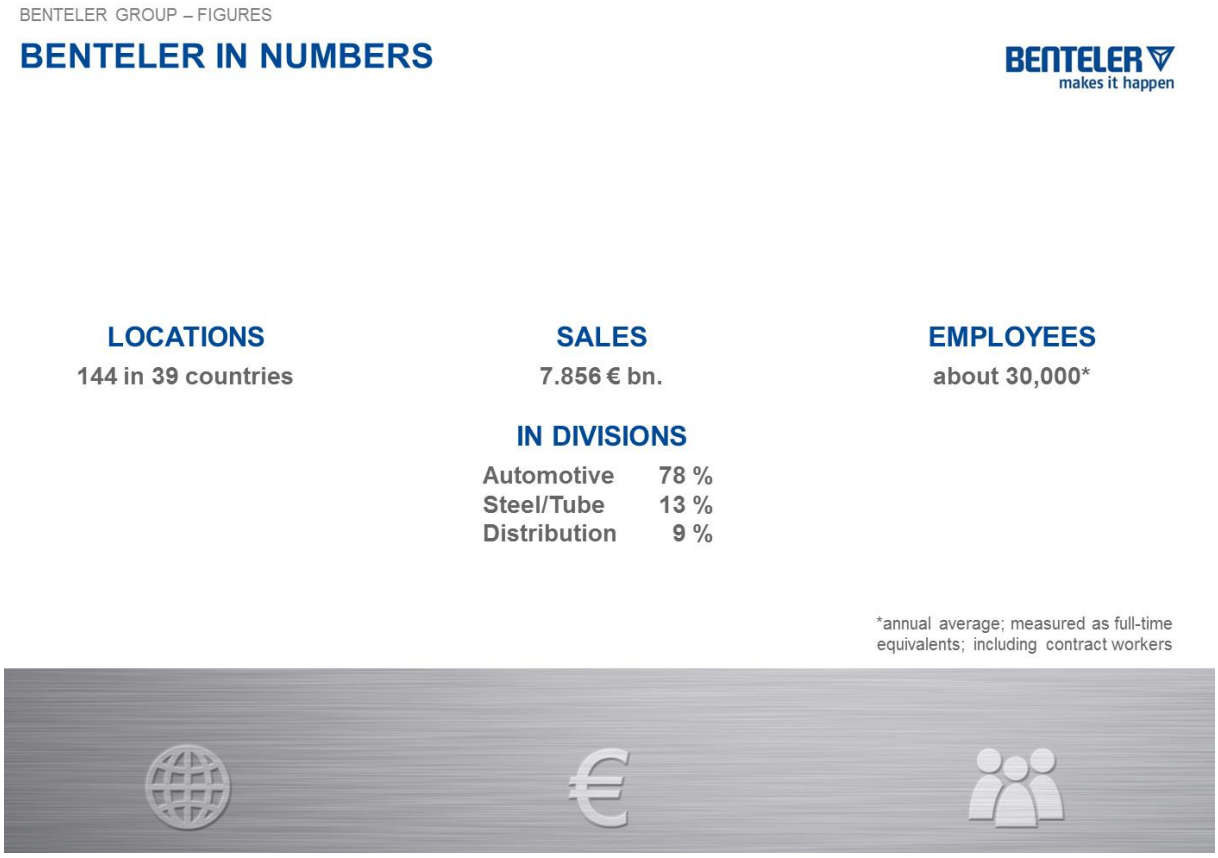

Figure 0-8 Benteler main figures

BENTELER Automotive supports almost all major vehicle manufacturers worldwide with development, production and services. The company's product portfolio includes components and modules for chassis, body, engine and exhaust systems. In close cooperation with business partners and customers, the leading automotive supplier develops and implements integrated solutions - with a focus on quality, safety and efficiency.

BENTELER Automotive's global production network consists of 75 plants in 24 countries with around 26,000 employees. This enables the company to offer its products and services to customers in almost every market worldwide. Accordingly, BENTELER opened a new plant in São Caetano do Sul, Brazil, and a sales office in Coventry, England, in 2017, in order to serve its target customers in the best possible way. In mid-2018, the company will start production at the new plant in Klášterec nad Ohří in the Czech Republic. BENTELER has been present in the Czech Republic since 1995 with its first plant. With the new plant, the company will operate five plants in the Czech Republic. In addition, BENTELER will open two

new plants in China in 2018: A module factory in Tianjin near Beijing, and a pressing plant in Chongqing. At the same time, BENTELER is expanding its location in Schwandorf (Bavaria) to meet the increased demand for electric mobility solutions. With this international production network, BENTELER is always a reliable and innovative business partner for its local customers.

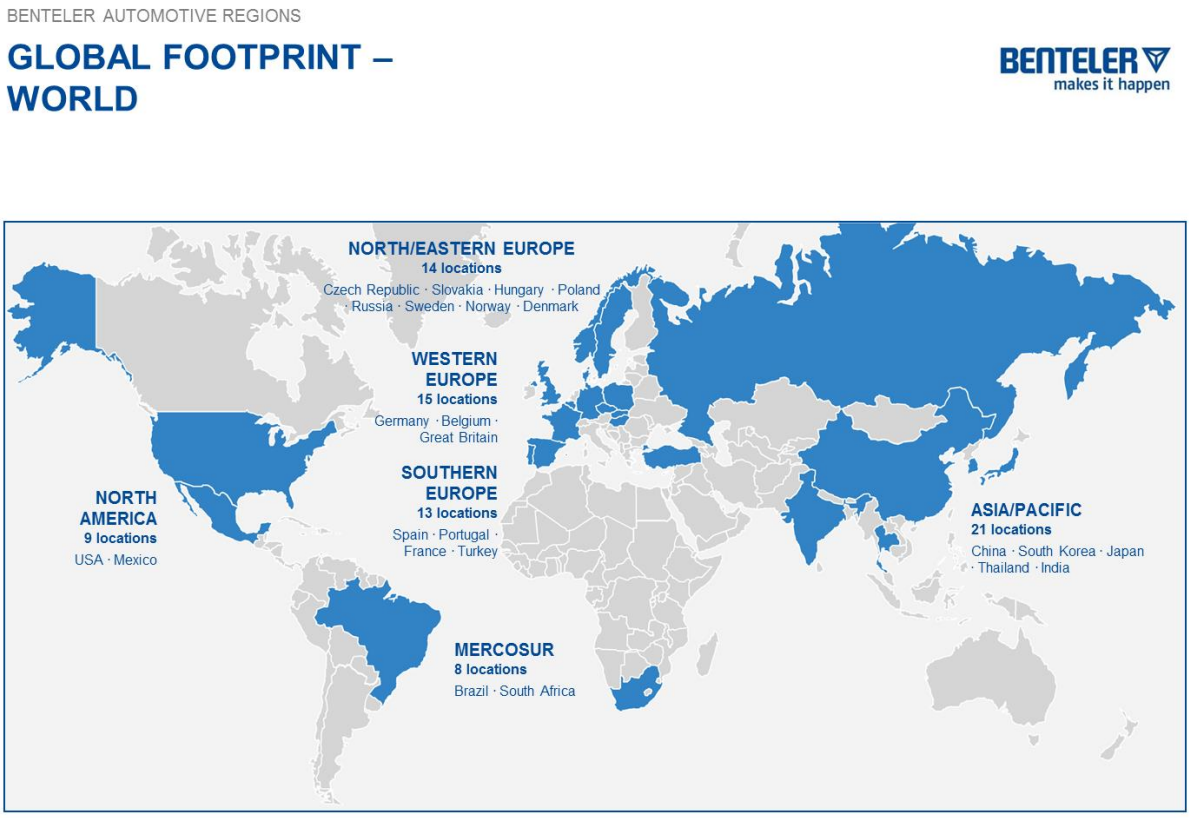

Figure 0-9 Benteler in the world

At BENTELER Automotive, sound expertise in the fields of vehicles and materials goes hand in hand with a constant striving for innovation. Based on comprehensive technical know-how, the company is a competent system partner for a wide range of automotive solutions - from chassis, engine and exhaust systems to structural components, machines and tools. Future-oriented and sustainable solutions for electric mobility are a focus of BENTELER Automotive's portfolio. These include innovations for electric vehicles, such as battery storage systems, front and rear axles, crash and temperature management and suspension systems.

BENTELER is a globally active company that develops, produces and sells products, systems and services for the automotive, energy and mechanical engineering sectors. As a family business in its fourth generation, 30,000 employees at 144 locations in 39

countries offer first-class manufacturing and sales expertise - passionately and close to the customer. Sales in fiscal 2017 amounted to 7.856 billion euros.

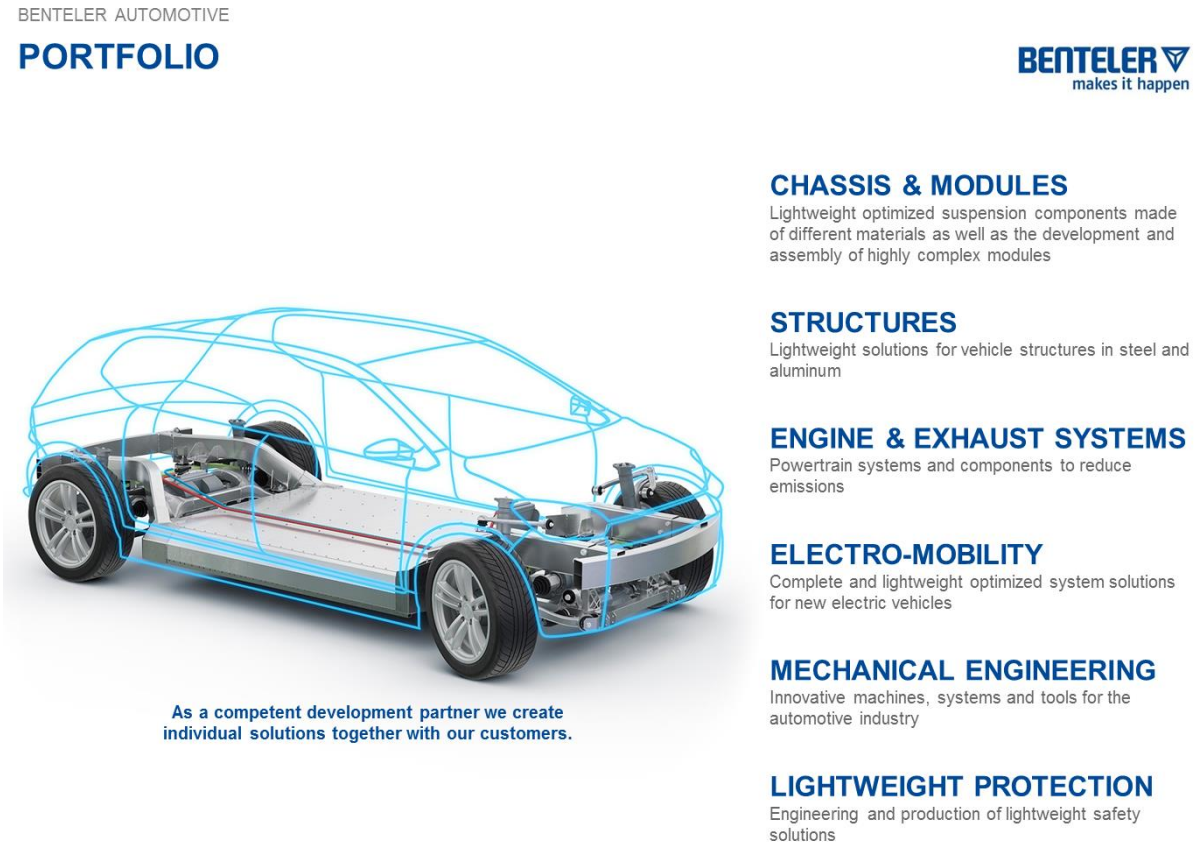

Figure 0-10 Benteler main products

10.2 Fraunhofer Institute for Mechatronic Systems Design

The Fraunhofer Institute for Mechatronic Systems Design IEM is a research institute of the Fraunhofer Gesellschaft, Europe's largest organization for applied research. The Fraunhofer Institute for Mechatronic Systems Design IEM is an expert for intelligent mechatronics in the context of industry 4.0. Scientists from the fields of mechanical engineering, software engineering and electrical engineering collaborate interdisciplinary at the Paderborn site. Focusing on "Advanced Systems Engineering", Fraunhofer IEM explores innovative methods and tools for the development of intelligent products, production systems and services. Underlying core competencies are intelligence in mechatronic systems, Systems Engineering and Virtual Prototyping. The field of Industrial Data Science is one important interdisciplinary competency for the development of intelligent products and production systems. It merges engineering know-how from the application domain with computer science, machine learning, mathematics and statistics.

The focus of Fraunhofer IEM lies in bringing Data Science methods to industrial applications. This includes the research of standard processes and methods for developing and managing Data Science projects, as well as experience in implementing and deploying data science solutions in enterprises. As part of the leading-edge cluster it's OWL, the Fraunhofer IEM has gained additional experience in working with and addressing the needs of small and medium-sized enterprises.

Fraunhofer IEM currently counts more than 100 staff members and is managed by a three-member steering committee: Prof. Ansgar Trächtler (executive director), Prof. Roman Dumitrescu and Prof. Eric Bodden. In 2016, the research volume was 8 million euros.

In 2011, Fraunhofer IEM started as a Project Group of the Fraunhofer Institute for Production Technology IPT in Aachen. Using a start-up funding from the state of North Rhine-Westphalia, the scientists developed a market-oriented research profile based on a strong cooperation with the regional industry. In 2016, just five years after the start of the Project Group, Fraunhofer IEM was admitted as an independent institution to the federal and state funding of the Fraunhofer-Gesellschaft. On January 1, 2017, it officially became an Institute.

Fraunhofer IEM has gained experience in the field of (big) data processing for industrial applications through a number of preceding projects, some of which are given as follows. “Intelligent Separator” focused on the development of an expert system based on a hybrid rule-based and data-driven knowledge representation for increased product quality and plant availability. “Process monitoring for reactive hot melt adhesive production” included Data analytics and development of a data-driven process monitor for chemical reactions involved in adhesive production. Adaptive Quality Assessment for enameled wire production processes encompassed Data analytics and development of an adaptive quality assessment framework for reduction of scrap production and laboratory testing

10.3 Atlantis Engineering

ATLANTIS Engineering is an SME with a long-standing experience in offering services and bespoke products to the manufacturing industry, with emphasis on the decision support for the management and optimisation of production activities and assets’ life-cycle, and on the streamlining of various maintenance related processes (predictive/condition-based). The company supports the clients in understanding and prioritising the manufacturing route, and in obtaining a holistic view of their plant performance.

ATLANTIS has successfully supported and organized more than 100 Technical Departments of manufacturing companies, service companies, hospitals, and ports through the implementation of an in-house developed Computerised Maintenance Management System (CMMS). In the same time, they have completed successfully several

advanced manufacturing and maintenance consulting, as well as Total Productive Maintenance (TPM) projects.

ATLANTIS is organising the annual "Greek Maintenance Forum" (www.maintenance-forum.eu); they are also the founding member of the Hellenic Maintenance Society (HMS) (www.hms-gr.eu); and the company's CEO is the Chairman of EFNMS (European Federation of National Maintenance Societies, www.efnms.org). The company is certified for quality management since 2009, according to the international standard EN ISO 9001.

Our main focus is on Smart Maintenance; core competences related to the proposal, include:

- Managing and optimising Enterprise Asset life cycle, through an in-house developed and continuously improved Asset Management **decision-support platform (mainDSS)**, which provides automated Auditing, Benchmarking and Recommendations.
- Interfacing with various types of metrology sensors (e. g. temperature, vibration, noise, leak detectors, etc.) in order to
    - ✓ apply Condition Monitoring methods in relation to predictive and corrective actions on production machinery;
    - ✓ calculate deterioration rate of machinery, predict failures in subsequent operation periods, and decide on possible alarms and activation of predictive maintenance strategies.
- Facilitating customers in obtaining a comprehensive view of the maintenance department structure and priorities by linking them with the company's strategy, through the in-house developed CMMS (Computerised Maintenance Management System), AIMMS.
- Developing and implementing integrated solutions in the field of production management in factories with simple or advanced manufacturing systems.
- Applying a holistic method that transforms TPM (Total Productive Maintenance) into a roadmap for achieving World Class Manufacturing.

ATLANTIS will bring to the project expertise related to automated decision support and recommendations for streamlining maintenance activities and synchronizing maintenance with production; towards smart maintenance. The main contribution in the project is in the Benteler smart maintenance and service pilot, developing: smart maintenance Strategies, risk assessment methods, machine-learning based automatic recommendations, smart maintenance DSS, synchronization and co-scheduling of maintenance with production activities. They will also contribute in KPI definition for technical evaluation and impact assessment.