INEVITABLE

OptImization aNd pErformance improVing In meTAl industry By digitaL tEchnologies

Deliverable 5.3

Design principles for data infrastructure

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Table of contents

List of Tables

List of Figures

Abbreviations and acronyms

CO	Confidential
CA	Consortium Agreement
COTS	Commercial-off-the-shelf
DB	Database
DSS	Decision Support System
EAF	Electric Arc Furnace
EHS	Environment, health and safety
ERP	Enterprise Resource Planning
GUI	Graphical User Interface
HMI	Human Machine Interface
HSE	Health, Safety and Environmental
HTTPS	Hyper Text Transfer Protocol Secure
IACS	Industrial Automation Control System
ICS	Industrial Cyber Security
IP	Internet Protocol
IPC	Industrial Personal Computer
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
MES	Manufacturing Execution System
OPC	Open Platform Communications
OT	Operation Technology
PLC	Programmable Logic Controller
PU	Public
PaaS	Platform-as-a-Service
SaaS	Software-as-a-Service
UC	Use Case
WP	Workpackage
ZRM	Sendzimir Rolling Mill

Abstract

The present document constitutes the deliverable **D5.3: "Preparation of design principles for the data infrastructure"** in the framework of the SPIRE project entitled "Optimization and performance improving in metal industry by digital technologies" (Project Acronym: INEVITABLE; Grant agreement no.: 869815).

The main objective of T5.3 was to prepare general design principles for the data infrastructure, based on the identified UC requirements and incorporating relevant industry standards as well as frameworks. The methodology for the preparation of the design principles considered the outcome of the final deliverables from tasks in WP2-WP4, their alignment with relevant experience in data infrastructure design and with the standards governing the industrial communication security as well as process of periodic validation in relation to all three use cases.

Resulting design principles will help partners implementing tasks within WP2-WP4 to align existing UC specific enabling technologies with industrial communication best practices, concepts, and capabilities. The document considers final requirements of the solutions developed within WP2-WP4 and planned for implementation within WP7-WP9, and its contents are complemented by D5.2: "Preparation of design principles for the communication infrastructure".

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1 Introduction

The aim of INEVITABLE project is to improve the performance indicators in the steel and nonferrous metals sectors by retrofitting existing production sites by digitalization and innovative control technologies, to elevate the overall digitalization level. Several digital enabling technologies will be developed and demonstrated on different Use cases. This document reports on the activities (Task 5.3) to elaborate design principles for the data infrastructure that needs to be prepared to enable the integration of the developed technologies into the existing ecosystem.

Work on task 5.3 was based on inputs and results from WP2 (D2.2 [1], D2.4 [2] and D2.6 [3]), where final requirements and specifications for each use case were identified. Final documents were studied for data infrastructure requirements, which were then aligned with standards, regulating data management in operational technology environments.

The work on Task 5.3 was conducted in parallel with the activities on task 5.2, which prepared the design principles for the communication infrastructure. Therefore, deliverables D5.2 ([1]) and D5.3 are also complementary in terms of the proposed methodology and should therefore be considered together. The detailed background with a presentation of the current trends in the definition of digital manufacturing ecosystems, how the industrial networks are organized and which standards support their implementation is presented in detail in the deliverable D5.2, to which the reader should refer. Since the design of the data and communication infrastructure is inextricably linked, the same methodology is used in the INEVITABLE project.

Each of the UCs is specific and depends on the existing infrastructure, the strategy of each partner and the digitalization perspective of the process variables, established in D5.1. All these factors influence the approach to prepare the optimal methodology for preparing the data infrastructure recommendations for the specific scenarios.

3 *Data infrastructure selection for INEVITABLE use cases*

Digital infrastructure is of key enablers of the cyber-physical convergence concept, along with most disruptive Industry 4.0 innovations. By linking the cyber and physical worlds, data from sensors and other sources is collected and forms the information layer of the RAMI4.0 that is an enabler for development of services and solutions.

Each use case comes from different organizational scenario, with unique environment and organizational requirements of final solution. Analysis of variables and the aspects as required for the design (defined in [4]), was performed and resulted on findings that adapted a general communication and data infrastructure principle.

All use cases used the same approach to variable evaluation, which provided basis for comparison of requirements and alignment to technical solutions, after qualitative evaluations were expanded with quantitative attribute estimates, based on the knowledge of current process, and documented in [4]. These values are required to support all the design steps needed to provide the required communication infrastructure.

Design of the OT infrastructure is made up of sequential steps, using elements of standard waterfall methodology [5], which ensures all necessary steps are taken to produce the desired outcome.

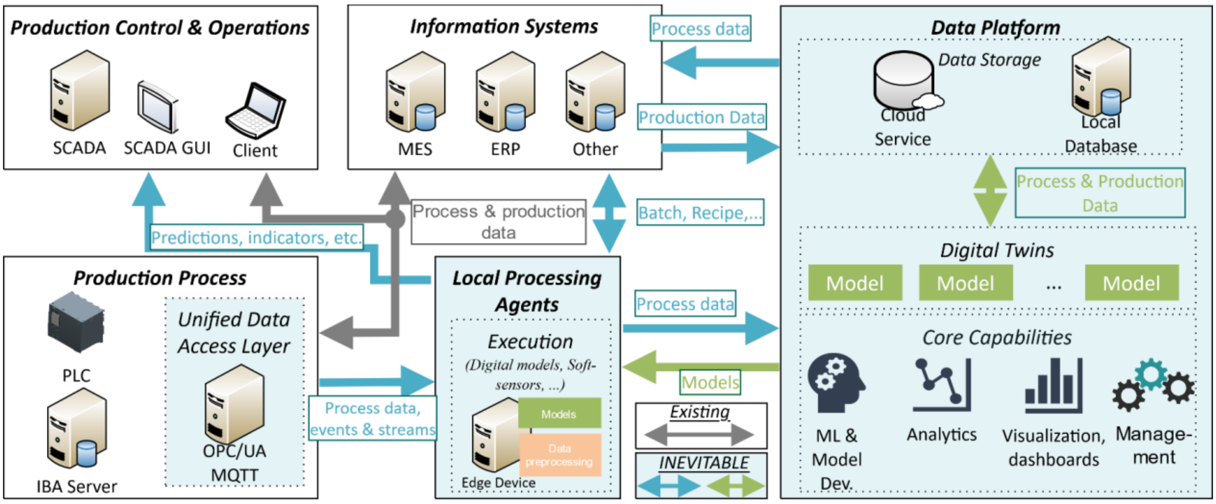

Figure 1 INEVITABLE example architecture - Use case 1

The method chosen for task 5.3 was analytical, focusing on the analysis of the requirements and specifications defined in WP2, which were prepared separately for each UC. The analysis was supported by the incorporation of data infrastructure design experience and cybersecurity standards for data management. On this basis, the design principles for the communication and data infrastructure were created, considering the RAMI4.0 and including IEC 62443 standard, as parts of it, specifically [6] and [7] relate to development of software solutions as well.

General overview of the methodology components is presented in Figure 2 and following sections describe individual stages.

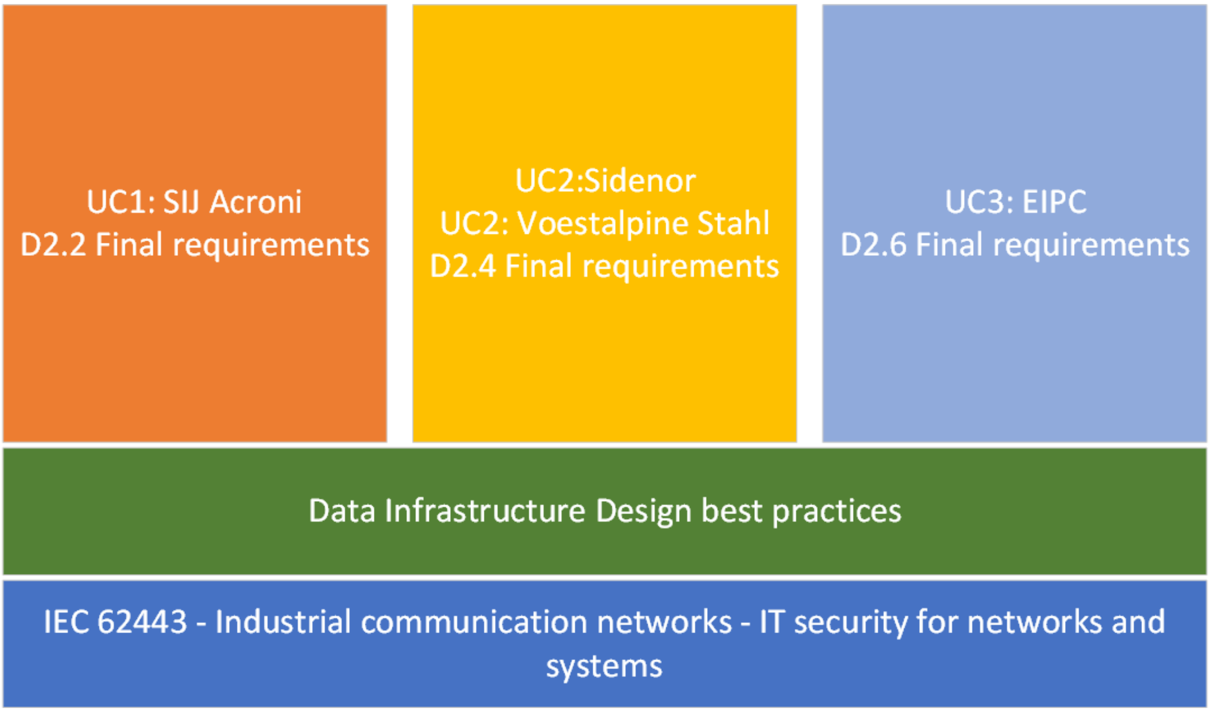

Figure 2 Methodology components for D5.3

Information for use cases was assembled using several approaches:

- Data collection with spreadsheets – in T5.1 supplemental technical attributes were defined and added to the requirements
- Interviews and meetings were held with responsible persons on each UC to obtain additional information
- Workshop was performed with teams from UC1 to explore the cloud/edge-based concept proposed by SIEMENS and transfer the knowledge to all stakeholders

3.1 Business requirements analysis

Deliverables D2.2 [1], D2.4 [8] and D2.6 [3] have identified final specifications and solution requirements for their respective use cases. These were examined for findings that relate or translate to technical requirements for data infrastructure. Furthermore, variables for each use case were extended by attributes defined in [9] which provided a basis for data infrastructure design principles preparation and validation.

3.1.1 Use Case 1: SIJ Acroni

UC 1 consists of two different industrial processes, installed at the ACRONI steel plant. The first process is the Electric Arc Furnace (EAF) process, which is considered as a process of primary metallurgy, while the second process, i.e., the cold-rolling mill (ZRM) is representative of the subsequent process of processing the coils in Cold Rolling Mill. Both processes have in common the development of the improvement of the process and plant data acquisition, improved process monitoring, development of decision support and provision of the advisory system, as shown in Figure 3. [1]

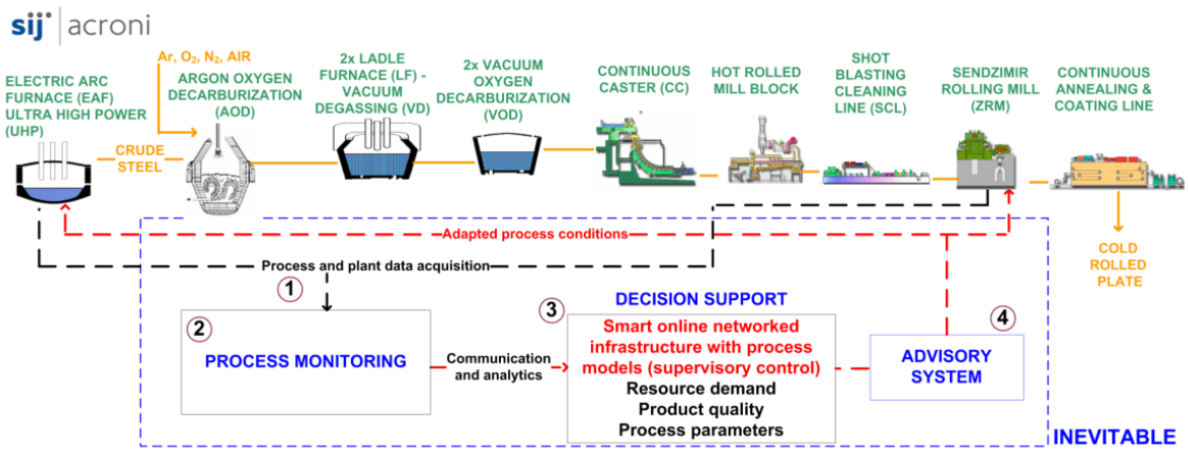

Figure 3 Online advisory and control system for the EAF and the ZRM cold-rolling process at ACRONI for Use Case 1

The improvement aimed for the EAF consists of two solutions. The first one covers the EAF process, which will be enhanced with proposed solution to advanced modelling and optimization methods. EAF process model will offer online and offline process simulation. Second solution is an EAF optimization framework, intended for offline optimization of the EAF process. [1]

Second part of Use Case 1 is ZRM process, which will be improved with analysis of collected process data and modelling techniques. [1]

Specifications and requirements for the EAF final solution

The EAF final solution consists of three components:

- Process measurement
- Development of algorithms
- Software implementation

Software implementation

Focus of Task 5.3, in relation to Use Case 1 – SIJ Acroni EAF is on software implementation data requirements.

Technology provider (UL), digitalization infrastructure provider (SIEMENS) and the end user (ACRONI) of the proposed software solutions, have defined the final specifications and requirements for the final software implementation, which also include the specifications and requirements for the hardware platform. These are as follows:

- access to all available process measurements from one on-line updated database source, i.e., measurements, which already exist today and measurements, which are still to be implemented should be captured and stored in one database, which is updated as soon as the measurement is performed,
- sufficient sampling frequency of process measurements, i.e., measured process values should be captured and stored with a sampling frequency, which corresponds to the nature of the physical variable, e.g., electrical values should normally be sampled with a higher sampling rate than for instance carbon or oxygen injection,
- sufficient processing power and computational speed, i.e., the selected HW/SW platform needs to assure execution of the simulation and optimization of the implemented algorithms in near-real-time, and thus allow proper representation of the obtained results without significant delay,

- proper display of the obtained results, i.e., the selected HW/SW platform needs to have the capability of designing an operational user-friendly HMI, which will be used for simplified interaction between the technology and the operator,
- edge and cloud computing platform, i.e., the selected HW/SW platform should be based on an edge and cloud computing concept, meaning that all captured data will be available, as well as all the calculations will be performed using a remote connection to the edge/cloud service using an independent local PC. [1]

Action plan for the EAF case

Based on evaluation of the Criticality and Digitalization potential of all considered process values the action plan was defined, that envisions activities that are needed to obtain digital access to all needed variables. These activities are focused mainly on connectivity upgrades as well as protocol upgrades. [1]

Gathering of additional attribute values

Based on [4] additional attribute values were collected as shown in Table 1.

Table 1 EAF process variables with additional attributes defined in T5.1

Process stage	Variable	Source	Critical	Datapoints/day	Protocol	Data type	UOM	Availability	Availability impact
EAF	steel grade	MES Database	5	24	Oracle DB	CHAR	/	<1 hour	Reduced model accuracy
EAF	start of heat	EAF PLC / OPC server	10	24	OPC	CHAR	/	No package loss	Model run cancelled
EAF	end of heat	EAF PLC / OPC server	7	24	OPC	CHAR	/	Package loss possible	Reduced model accuracy
EAF	tap-to-tap time	MES Database	1	24	Oracle DB	REAL	min	Outage is not critical	No influence
EAF	power-on time	MES Database	1	24	Oracle DB	REAL	min	Outage is not critical	No influence
EAF	furnace flap status(Open/closed)	EAF PLC / OPC server	1	144	OPC	BOOL	/	Outage is not critical	Reduced model accuracy
EAF	basket weight	EAF PLC / OPC server	1	72	OPC	REAL	t	Outage is not critical	No influence
EAF	power switch status (On/Off)	EAF PLC / OPC server	10	720	OPC	BOOL	/	No package loss	Model run cancelled
EAF	heat kwh counter value	EAF PLC / OPC server	1	720	OPC	INT	kWh	Outage is not critical	No influence
EAF	Qxygen valve status (On/Off)	EAF PLC / OPC server	3	720	OPC	BOOL	/	Outage is not critical	No influence
EAF	heat Oxygen counter value	EAF PLC / OPC server	1	720	OPC	REAL	m3	Outage is not critical	No influence
EAF	initial hotheel estimate	MES Database	5	24	Oracle DB	REAL	t	<1 day	Reduced model accuracy
EAF	endpoint hotheel estimate	MES Database	5	24	Oracle DB	REAL	t	<1 day	Reduced model accuracy
EAF	start of basket charging	EAF PLC / OPC server	10	72	OPC	BOOL	/	No package loss	Model run cancelled
EAF	end of basket charging	EAF PLC / OPC server	10	72	OPC	BOOL	/	No package loss	Model run cancelled
EAF	overall basket weight	MES Database	1	72	Oracle DB	REAL	t	Outage is not critical	No influence
EAF	material types in basket	MES Database	10	720	Oracle DB	DWORD	/	No package loss	Model run cancelled
EAF	material weights in basket	MES Database	10	720	Oracle DB	REAL	t	No package loss	Model run cancelled
EAF	bath temperature sampling time and value	TCPIP message from meas.device	10	72	TCP IP msg	REAL	°C	No package loss	Reduced model accuracy
EAF	bath ppm O2 sampling time and value	TCPIP message from meas.device	8	72	TCP IP msg	REAL	ppm	Package loss possible	Reduced model accuracy
EAF	bath composition sampling time	EAF PLC / OPC server	1	24	OPC	BOOL	/	Outage is not critical	No influence
EAF	bath composition value	MES Database	1	24	Oracle DB	REAL	%	Outage is not critical	No influence
EAF	slag composition sampling time	EAF PLC / OPC server	1	24	OPC	BOOL	/	Outage is not critical	No influence
EAF	slag composition value	MES Database	1	24	Oracle DB	REAL	%	Outage is not critical	No influence
EAF	active transformer power	EAF PLC / OPC server	10	43200	OPC	REAL	MW	No package loss	Model run cancelled
EAF	continuous carbon addition/flow	EAF PLC / OPC server	10	8640	OPC	REAL	kg/min	No package loss	Model run cancelled
EAF	continuous oxygen addition/flow	EAF PLC / OPC server	10	8640	OPC	REAL	m3/h	No package loss	Model run cancelled
EAF	carbon addition amount (individual charge)	EAF PLC / OPC server	10	256	OPC	INT	kg	No package loss	Model run cancelled
EAF	slag formers amount (individual charge)	EAF PLC / OPC server	10	256	OPC	INT	t	No package loss	Model run cancelled
EAF	alloy addition amount (individual charge)	EAF PLC / OPC server	10	256	OPC	INT	t	No package loss	Model run cancelled
EAF	temperatures of water-cooled panels (36 meas.points)	EAF PLC / OPC server	1	8640	OPC	INT	°C	Outage is not critical	No influence
EAF	water flows of water-cooled panels (2 meas. points)	EAF PLC / OPC server	1	8640	OPC	REAL	m3/h	Outage is not critical	No influence

Table contains required information to predict the amount of collected data, as well as its criticality. We can see from the value of variables in the frequency "Datapoints/day" column that some variables are read up to every 2 to 10 seconds. Data loss in these cases is inadmissible, as model would not have needed data to run.

Specifications and requirements for the ZRM case

For the ZRM Use Case two main targets were identified:

- **Online adaptation of recipes**: The definition of rolling plan prior to beginning of the operations. The aim is to define the optimal rolling recipe parameters, which will be accomplished by observing the historical performance and process dynamics.
- **Anomaly detection**: Post-processing of the operational data and scanning for anomalies, which will be accomplished by validating the physical relations among the measured parameters and studying the statistical consistency of measured process parameters and control loops

The ZRM final solution consists of three components:

- Process measurements

- Development of algorithms
- Software implementation

Software implementation

Focus of activities in T5.1 for Use Case 1 – SIJ Acroni ZRM is on software implementation, related to data requirements.

Final specifications and requirements for the final solution implementation are:

- All needed process measurements should be accessible through OPC UA protocol (IBA) or SQL queries (MES system).
- Implementation platform should enable short local memory to store measurements of one pass or one rolling phase.
- Sampling frequency of the variables should be fast enough to detect DC drive anomalies.
- The platform should enable deployment or integration of the Python code and management of the Python environment.
- Final solution should be deployed locally on the cloud and on the cloud/server platform. Cloud/server platform should provide possibilities to deploy html server and web-services developed in Python.
- Internet access at the production process is needed to display web-browser based HMI or access the developed web-services.
- Edge device should be capable to execute batch post-processing of the measured operational data.
- Long-term management of the edge platform should be provided. Moreover, direct access to the edge should be provided to perform debugging and model versioning.

Gathering of additional attribute values

Based on [4] additional attribute values were collected as shown in Table 2.

Table 2 ZRM variables with additional attributes defined in T5.1

Process stage	Variable	Source	Reading frequency	Storing Frequenc	Nr. of variabl	Samples per one rolling	Protocol	Data typ	Data format - storage	Data acquisition concept	Criticality
Input material	Steel properties	MES system	1	1	29	1	Oracle DB	REAL	Parameter	DB Query	7
Rolling recipe	Rolling recipe	MES system	1	1	21	5	Oracle DB	REAL	Parameter	DB Query	8
Electrical drives	Armature current	IBA system	1	1	8	36000	MQTT (IBA)	REAL	Time Series	Push	10
Electrical drives	Field current	IBA system	1	1	0	36000	MQTT (IBA)	REAL	Time Series	Push	10
Electrical drives	Armature voltage	IBA system	1	1	0	36000	MQTT (IBA)	REAL	Time Series	Push	10
Electrical drives	Field voltage	IBA system	1	1	0	36000	MQTT (IBA)	REAL	Time Series	Push	10
Electrical drives	Torque	IBA system	1	1	8	36000	MQTT (IBA)	REAL	Time Series	Push	8
Electrical drives	Angular velocity	IBA system	1	1	8	36000	MQTT (IBA)	REAL	Time Series	Push	10
Electrical drives	Gear ratio	IBA system	1	1	4	1	MQTT (IBA)	REAL	Parameter	Push	9
Electrical drives	Diameter of reels and coils	IBA system	1	1	9	36000	MQTT (IBA)	REAL	Time Series	Push	8
Deflection rolls	Diameter	IBA system	1	1	2	1	MQTT (IBA)	REAL	Parameter	Push	8
Deflection rolls	Gear ratio	IBA system	1	1	2	1	MQTT (IBA)	REAL	Parameter	Push	8
Deflection rolls	Angular velocity	IBA system	1	1	2	36000	MQTT (IBA)	REAL	Time Series	Push	10
GAP Control	Rolling pressure	IBA system	1	1	2	36000	MQTT (IBA)	REAL	Time Series	Push	10
GAP Control	Input thickness	IBA system	1	1	2	36000	MQTT (IBA)	REAL	Time Series	Push	10
GAP Control	Output thickness	IBA system	1	1	2	36000	MQTT (IBA)	REAL	Time Series	Push	10
GAP Control	Back tension	IBA system	1	1	2	36000	MQTT (IBA)	REAL	Time Series	Push	10
GAP Control	Front tension	IBA system	1	1	1	36000	MQTT (IBA)	REAL	Time Series	Push	10
GAP Control	Rolling control type	IBA system	1	1	8	100	MQTT (IBA)	BOOL	Event	Push	6
GAP Control	Actuator command	IBA system	1	1	2	36000	MQTT (IBA)	REAL	Time Series	Push	8
GAP Control	Gap	IBA system	1	1	2	36000	MQTT (IBA)	REAL	Time Series	Push	8
Profile control	Strip profile	Flatness system	1	1	?	36000	MQTT (IBA)	REAL	Time Series	Push	8
Profile control	Crown position	IBA system	1	1	5	36000	MQTT (IBA)	REAL	Time Series	Push	8
Profile control	Crown control commands	IBA system	1	1	5	36000	MQTT (IBA)	REAL	Time Series	Push	8
General	width of coil	MES system	1	1	1	1	Oracle DB	REAL	Parameter	DB Query	4
General	Rolling pass start	MES system	1	1	1	5	Oracle DB	TIME	Event	DB Query	8
General	Rolling pass end	MES system	1	1	1	5	Oracle DB	TIME	Event	DB Query	8
General	Pass number	MES system	1	1	1	5	Oracle DB	INT	Event	DB Query	8

Based on the data collected, we can see that most of the process variables have low frequency, but each rolling cycle contains a large number of samples for most of the observed variables, that need to be collected to provide necessary data for analysis.

Digital infrastructure in SIJ Acroni

SIJ Acroni is in the process of validating the proposed industrial cloud-based solution with edge capabilities, to provide a basis for EAF and ZRM model processing. The architecture of the proposed system is shown in Figure 4. If validation is completed successfully, further activities will take place within WP7, focused on implementation of the proposed solution. An example of topology of this solution within UC1 is illustrated in Figure 5.

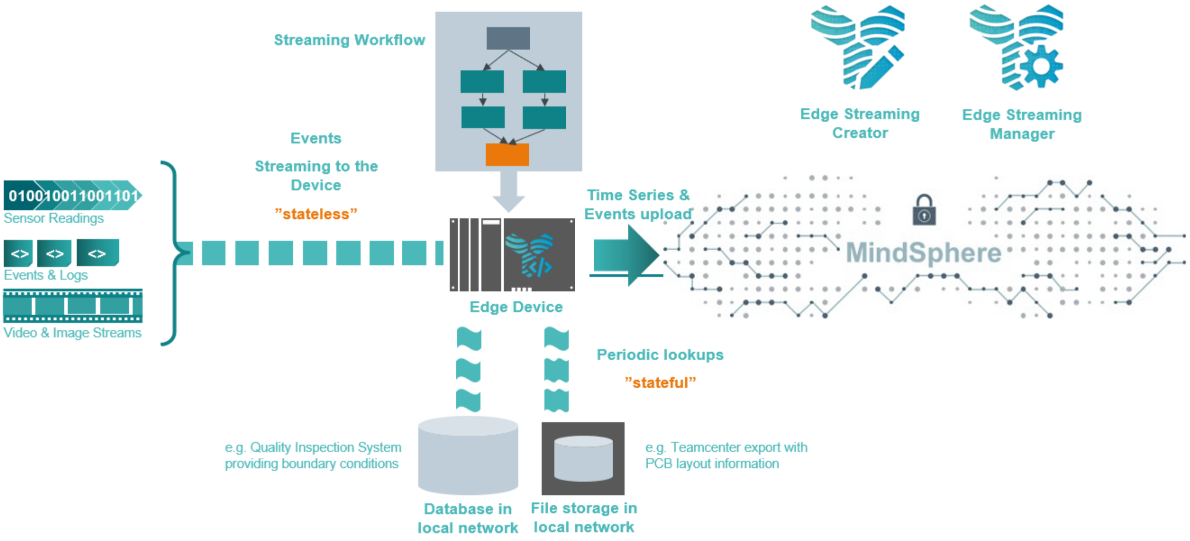

Figure 4 Industrial cloud-based platform with edge computing

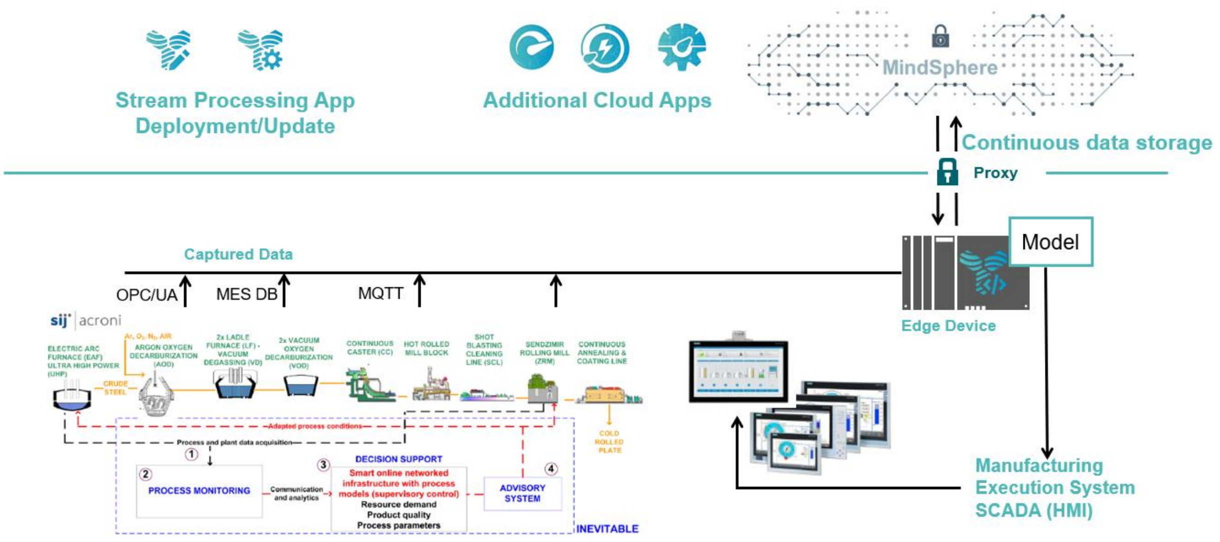

Figure 5 Topology of the cloud-based solution in UC1 context

3.1.2 Use Case 2: Sidenor

UC2 SID D2.4 addresses the final requirements and specifications related to ultra clean steel production, specifically reduction in poor castability cases and achieving premium cleanliness of steel. This will be achieved through improved digitalization, specifically with development and integration of dedicated surveillance system in the process, illustrated in Figure 6. [8]

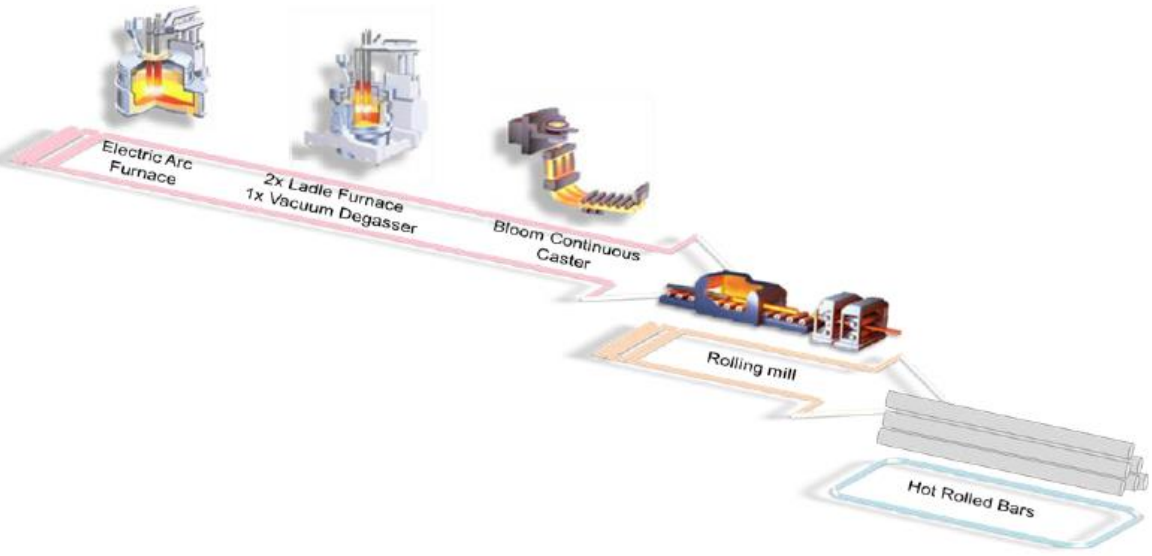

Figure 6 Steelmaking process at SID [8]

Through activities carried out in T2.4, variables that are important for KPIs were identified and subdivided in process stages.

These were then rated for quality in different categories and their role in KPI calculation. The output was then used to define an action plan, with actions related to either:

- Improving quality of data (process related)
- Digitalization of variables

Further activities on UC2 SID will take place in WP4 and WP8, with the development of software solution for sensor data analysis and model-based decision support system.

3.1.3 Use Case 2: Voestalpine

UC2 VAS D2.4 addresses the final requirements and specifications related to ultra clean steel production, specifically the optimization of stirring efficiency and homogenization in ladle furnace and vacuum degassing plants, to achieve required steel quality in optimal treatment times. The process where improvements will be carried out is illustrated in Figure 7.

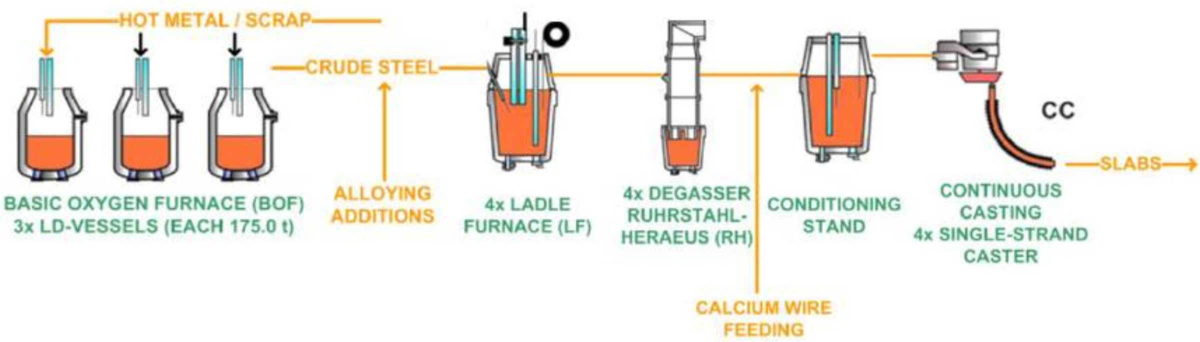

Figure 7 Steelmaking process at VAS [8]

Through activities carried out in T2.4, necessary variables for model development, smart sensor integration and decision support system were identified and subdivided into process stages.

These were then rated for quality in different categories and their role in KPI calculation. The output was then used to define an action plan, with actions related to either:

- Improving quality of data (process related)
- Digitalization of variables

Further activities on UC2 VAS will take place in WP4 and WP8, with the development of software solution for sensor data analysis and model-based decision support system.

As-is data infrastructure in UC2 VAS is illustrated below in Figure 8. Infrastructure contains:

- Oracle ODBC database storage and archive
- CAQC-SM system
- Optical data and signals
- Level 1 process signals.

From Figure 8 we can also see that communication in field level is based on proprietary developed VAS telegram and OPC packets, which are open standard based. Communication infrastructure is covered in more detail in [10].

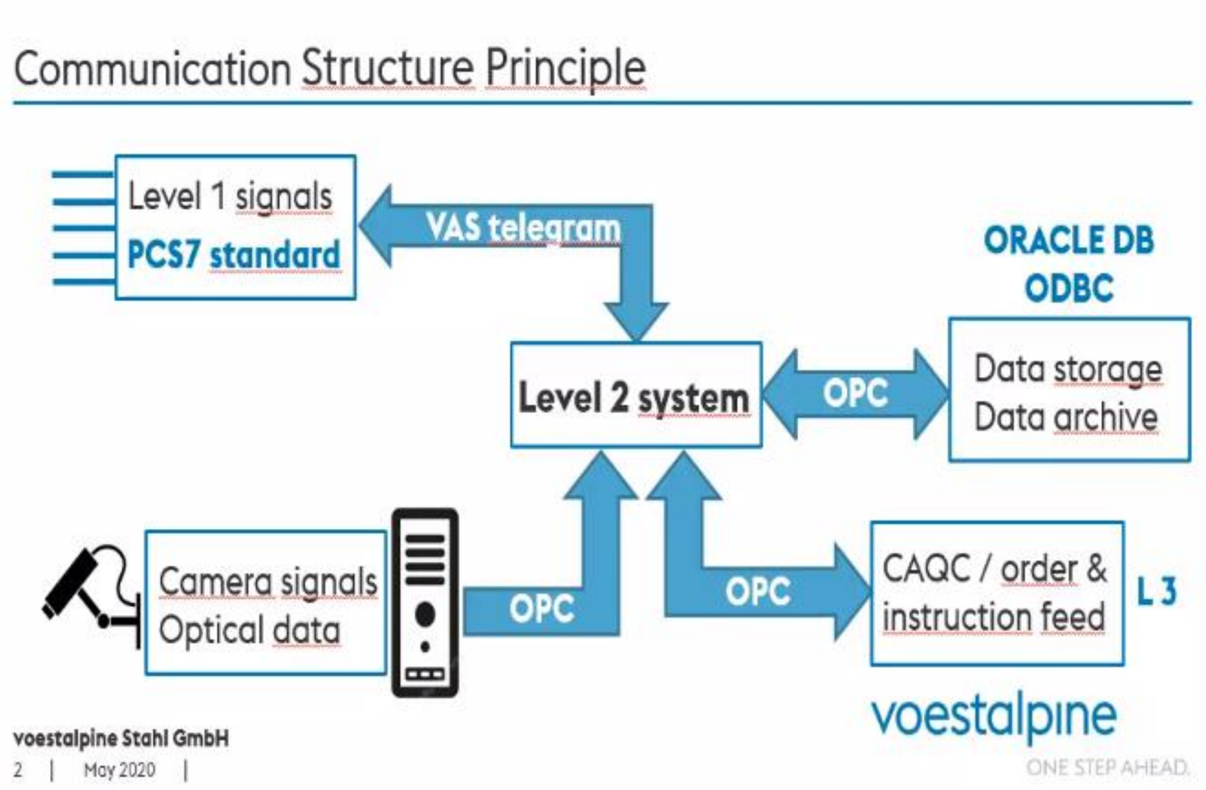

Figure 8 VAS communication and data structure. (Voestalpine Stahl GmbH, 2020)

Gathering of additional attribute values

Based on [4] additional attribute values were collected as shown in Table 3 and Table 4.

Table 3 VAS process related variables with additional attributes part I

Process stage	Variable	Source	protocol	Datapoint	Reading frequency	Availability	Availability impact
BOF converter process	Steel composition	CAQC / Level 3	OPC	200	2-Medium (every few minutes)	no package loss	model run cancelled
BOF converter process	Temperature (°C)	S7 / Oracle DB	VASst / OPC	200	2-Medium (every few minutes)	no package loss	Reduced model accurac
BOF converter process	Total oxygen (ppm)	S7 / Oracle DB	VASst / OPC	200	2-Medium (every few minutes)	no package loss	model run cancelled
Tapping - BOF	Slag carryover from BOF to ladle (index)	S7 / Oracle DB	VASst / OPC	100	1-Low (once per hour)	package loss possible	Reduced model accurac
Tapping - BOF	alloy addition (kg)	Level 3 / S7	OPC / VASst	100	2-Medium (every few minutes)	no package loss	model run cancelled
Tapping - BOF	C addition (kg)	Level 3 / S7	OPC / VASst	100	2-Medium (every few minutes)	no package loss	Reduced model accurac
Tapping - BOF	addition of slag formers (kg)	Level 3 / S7	OPC / VASst	100	2-Medium (every few minutes)	package loss possible	model run cancelled
Tapping - BOF	Start slag weight (kg)	S7 / Oracle DB	VASst / OPC	100	1-Low (once per hour)	package loss possible	Reduced model accurac
Tapping - BOF	Start steel weight (kg)	S7 / Oracle DB	VASst / OPC	100	1-Low (once per hour)	no package loss	Reduced model accurac
Tapping - BOF	Tapping start (min)	S7 / Oracle DB	VASst / OPC	100	1-Low (once per hour)	outage is not critical	no influence
Tapping - BOF	Tapping time (min)	S7 / Oracle DB	VASst / OPC	100	1-Low (once per hour)	outage is not critical	no influence
Complete metallurgy	Ladle empty time (min)	S7 / Oracle DB	VASst / OPC	100	1-Low (once per hour)	package loss possible	Reduced model accurac
Complete metallurgy	Ladle filled time (min)	S7 / Oracle DB	VASst / OPC	100	1-Low (once per hour)	package loss possible	Reduced model accurac
Complete metallurgy	Ladle preheating time (min)	S7 / Oracle DB	VASst / OPC	10	1-Low (once per hour)	outage is not critical	no influence
Complete metallurgy	Ladle preheating temperature (°C)	S7 / Oracle DB	VASst / OPC	10	1-Low (once per hour)	outage is not critical	no influence
Complete metallurgy	Ladle age (nr of casts)	S7 / Oracle DB	VASst / OPC	100	1-Low (once per hour)	outage is not critical	no influence
Complete metallurgy	Ladle working time (min)	S7 / Oracle DB	VASst / OPC	100	1-Low (once per hour)	outage is not critical	no influence
Complete metallurgy	Ladle number	S7 / Oracle DB	VASst / OPC	100	1-Low (once per hour)	outage is not critical	no influence
Complete metallurgy	Amount and remaining slag in the ladle from previous cast	S7 / Oracle DB	VASst / OPC	100	2-Medium (every few minutes)	package loss possible	Reduced model accurac
Complete metallurgy	Steel composition	CAQC / Level 3	OPC	500	2-Medium (every few minutes)	no package loss	model run cancelled
Complete metallurgy	Non metallic inclusion data	Level 3 / S7	OPC / VASst	400	1-Low (once per hour)	package loss possible	model run cancelled
Complete metallurgy	Temperature (°C)	S7 / Oracle DB	VASst / OPC	500	2-Medium (every few minutes)	no package loss	Reduced model accurac
Alloying - Ladle Furnace	alloy addition (kg)	Level 3 / S7	OPC / VASst	500	2-Medium (every few minutes)	no package loss	model run cancelled
Alloying - Ladle Furnace	alloy time (min)	S7 / Oracle DB	VASst / OPC	500	2-Medium (every few minutes)	package loss possible	Reduced model accurac
Alloying - Ladle Furnace	addition of slag formers (kg)	Level 3 / S7	OPC / VASst	200	2-Medium (every few minutes)	no package loss	model run cancelled
Alloying - Ladle Furnace	addition of slag formers time (min)	S7 / Oracle DB	VASst / OPC	200	2-Medium (every few minutes)	package loss possible	Reduced model accurac
Alloying - Ladle Furnace	addition of desulphurisation agent (kg)	Level 3 / S7	OPC / VASst	86400	3-High (every few seconds)	package loss possible	model run cancelled
Alloying - Ladle Furnace	addition of desulphurisation agent time (min)	S7 / Oracle DB	VASst / OPC	86400	3-High (every few seconds)	package loss possible	Reduced model accurac
Alloying - Ladle Furnace	addition of desulphurisation agent duration (min)	S7 / Oracle DB	VASst / OPC	86400	3-High (every few seconds)	package loss possible	Reduced model accurac
Heating - Ladle Furnace	Total electric energy at ladle furnace (kWh)	CAQC / Level 3	OPC	86400	3-High (every few seconds)	no package loss	Reduced model accurac
Heating - Ladle Furnace	total heating time at ladle furnace (min)	S7 / Oracle DB	VASst / OPC	86400	3-High (every few seconds)	no package loss	Reduced model accurac
Purging - Ladle Furnace	Stirring start (min)	Level 3 / S7	OPC / VASst	86400	3-High (every few seconds)	no package loss	model run cancelled
Purging - Ladle Furnace	Stirring gas type (Ar/N2)	Level 3 / S7	OPC / VASst	86400	3-High (every few seconds)	no package loss	Reduced model accurac
Purging - Ladle Furnace	Stirring gas flow (m³/h)	CAQC / Level 3	OPC	86400	3-High (every few seconds)	package loss possible	model run cancelled
Purging - Ladle Furnace	Stirring gas backpressure (bar)	S7 / Oracle DB	VASst / OPC	86400	3-High (every few seconds)	package loss possible	Reduced model accurac
Purging - Ladle Furnace	Stirring efficiency	S7 / Oracle DB	VASst / OPC	86400	3-High (every few seconds)	package loss possible	model run cancelled
Purging - Ladle Furnace	desulphurisation efficiency	CAQC / Level 3	OPC	86400	3-High (every few seconds)	package loss possible	model run cancelled
Degassing - RH Degasse	Stirring gas type (Ar/N2)	CAQC / Level 3	OPC	86400	3-High (every few seconds)	no package loss	Reduced model accurac
Degassing - RH Degasse	Stirring gas flow (m³/h)	CAQC / Level 3	OPC	86400	3-High (every few seconds)	package loss possible	model run cancelled
Degassing - RH Degasse	Stirring gas backpressure (bar)	S7 / Oracle DB	VASst / OPC	86400	3-High (every few seconds)	package loss possible	Reduced model accurac
Degassing - RH Degasse	Number of tubes in operation	S7 / Oracle DB	VASst / OPC	86400	3-High (every few seconds)	no package loss	Reduced model accurac
Degassing - RH Degasse	Treatment time (min)	S7 / Oracle DB	VASst / OPC	86400	3-High (every few seconds)	no package loss	Reduced model accurac
Degassing - RH Degasse	Vessel pressure (bar)	S7 / Oracle DB	VASst / OPC	86400	3-High (every few seconds)	no package loss	Reduced model accurac
Degassing - RH Degasse	offgas amount (m3/h)	S7 / Oracle DB	VASst / OPC	86400	3-High (every few seconds)	outage is not critical	no influence
Degassing - RH Degasse	offgas analysis	S7 / Oracle DB	VASst / OPC	86400	3-High (every few seconds)	outage is not critical	no influence
Degassing - RH Degasse	circulation rate	S7 / Oracle DB	VASst / OPC	86400	3-High (every few seconds)	outage is not critical	no influence
Casting - Continuous Ca	Ladle free /oxygen opening	S7 / Oracle DB	VASst / OPC	10	2-Medium (every few minutes)	no package loss	Reduced model accurac
Casting - Continuous Ca	Tundish preheating duration (min)	S7 / Oracle DB	VASst / OPC	100	1-Low (once per hour)	no package loss	Reduced model accurac
Casting - Continuous Ca	Tundish cover addition (kg)	CAQC / Level 3	OPC	100	2-Medium (every few minutes)	package loss possible	Reduced model accurac
Casting - Continuous Ca	Casting duration (min)	Level 3 / S7	OPC / VASst	86400	3-High (every few seconds)	no package loss	model run cancelled
Casting - Continuous Ca	Position of cast in the casting sequence	CAQC / Level 3	OPC	100	2-Medium (every few minutes)	no package loss	Reduced model accurac
Casting - Continuous Ca	Ladle shroud inertisation	CAQC / Level 3	OPC	86400	3-High (every few seconds)	package loss possible	Reduced model accurac
Casting - Continuous Ca	Steel composition	CAQC / Level 3	OPC	200	2-Medium (every few minutes)	no package loss	model run cancelled
Casting - Continuous Ca	Clogging number	S7 / Oracle DB	VASst / OPC	86400	3-High (every few seconds)	package loss possible	Reduced model accurac

Table 4 VAS process related variables with additional attributes part II - storage related properties

Process stage	Variable	Storing Frequency	storage frequency	storage after compressi	data typ
BOF converter process	Steel composition	2-Medium (every few minutes)	2 months	>36 months	CHAR
BOF converter process	Temperature (°C)	2-Medium (every few minutes)	2 months	>36 months	REAL
BOF converter process	Total oxygen (ppm)	2-Medium (every few minutes)	2 months	>36 months	CHAR
Tapping - BOF	Slag carryover from BOF to ladle (index)	1-Low (once per hour)	2 months	>36 months	REAL
Tapping - BOF	alloy addition (kg)	2-Medium (every few minutes)	2 months	>36 months	REAL
Tapping - BOF	C addition (kg)	2-Medium (every few minutes)	2 months	>36 months	REAL
Tapping - BOF	addition of slag formers (kg)	2-Medium (every few minutes)	2 months	>36 months	REAL
Tapping - BOF	Start slag weight (kg)	1-Low (once per hour)	2 months	>36 months	REAL
Tapping - BOF	Start steel weight (kg)	1-Low (once per hour)	2 months	>36 months	REAL
Tapping - BOF	Tapping start (min)	1-Low (once per hour)	2 months	>36 months	REAL
Tapping - BOF	Tapping time (min)	1-Low (once per hour)	2 months	>36 months	REAL
Complete metallurgy	Ladle empty time (min)	1-Low (once per hour)	2 months	>36 months	REAL
Complete metallurgy	Ladle filled time (min)	1-Low (once per hour)	2 months	>36 months	REAL
Complete metallurgy	Ladle preheating time (min)	1-Low (once per hour)	2 months	>36 months	REAL
Complete metallurgy	Ladle preheating temperature (°C)	1-Low (once per hour)	2 months	>36 months	REAL
Complete metallurgy	Ladle age (nr of casts)	1-Low (once per hour)	2 months	>36 months	CHAR
Complete metallurgy	Ladle working time (min)	1-Low (once per hour)	2 months	>36 months	REAL
Complete metallurgy	Ladle number	1-Low (once per hour)	2 months	>36 months	CHAR
Complete metallurgy	Amount and remaining slag in the ladle from previous cast	2-Medium (every few minutes)	2 months	>36 months	CHAR
Complete metallurgy	Steel composition	2-Medium (every few minutes)	2 months	>36 months	CHAR
Complete metallurgy	Non metallic inclusion data	1-Low (once per hour)	2 months	>36 months	CHAR
Complete metallurgy	Temperature (°C)	2-Medium (every few minutes)	2 months	>36 months	REAL
Alloying - Ladle Furnace	alloy addition (kg)	2-Medium (every few minutes)	2 months	>36 months	REAL
Alloying - Ladle Furnace	alloy time (min)	2-Medium (every few minutes)	2 months	>36 months	REAL
Alloying - Ladle Furnace	addition of slag formers (kg)	2-Medium (every few minutes)	2 months	>36 months	REAL
Alloying - Ladle Furnace	addition of slag formers time (min)	2-Medium (every few minutes)	2 months	>36 months	REAL
Alloying - Ladle Furnace	addition of desulphurisation agent (kg)	3-High (every few seconds)	2 months	>36 months	REAL
Alloying - Ladle Furnace	addition of desulphurisation agent time (min)	3-High (every few seconds)	2 months	>36 months	REAL
Alloying - Ladle Furnace	addition of desulphurisation agent duration (min)	3-High (every few seconds)	2 months	>36 months	REAL
Heating - Ladle Furnace	Total electric energy at ladle furnace (kWh)	3-High (every few seconds)	2 months	>36 months	CHAR
Heating - Ladle Furnace	total heating time at ladle furnace (min)	3-High (every few seconds)	2 months	>36 months	REAL
Purging - Ladle Furnace	Stirring start (min)	3-High (every few seconds)	2 months	>36 months	REAL
Purging - Ladle Furnace	Stirring gas type (Ar/N2)	3-High (every few seconds)	2 months	>36 months	CHAR
Purging - Ladle Furnace	Stirring gas flow (m³/h)	3-High (every few seconds)	2 months	>36 months	CHAR
Purging - Ladle Furnace	Stirring gas backpressure (bar)	3-High (every few seconds)	2 months	>36 months	CHAR
Purging - Ladle Furnace	Stirring efficiency	3-High (every few seconds)	2 months	>36 months	CHAR
Purging - Ladle Furnace	desulphurisation efficiency	3-High (every few seconds)	2 months	>36 months	CHAR
Degassing - RH Degasse	Stirring gas type (Ar/N2)	3-High (every few seconds)	2 months	>36 months	CHAR
Degassing - RH Degasse	Stirring gas flow (m³/h)	3-High (every few seconds)	2 months	>36 months	CHAR
Degassing - RH Degasse	Stirring gas backpressure (bar)	3-High (every few seconds)	2 months	>36 months	CHAR
Degassing - RH Degasse	Number of tubes in operation	3-High (every few seconds)	2 months	>36 months	CHAR
Degassing - RH Degasse	Treatment time (min)	3-High (every few seconds)	2 months	>36 months	REAL
Degassing - RH Degasse	Vessel pressure (bar)	3-High (every few seconds)	2 months	>36 months	CHAR
Degassing - RH Degasse	offgas amount (m3/h)	3-High (every few seconds)	2 months	>36 months	CHAR
Degassing - RH Degasse	offgas analysis	3-High (every few seconds)	2 months	>36 months	CHAR
Degassing - RH Degasse	circulation rate	3-High (every few seconds)	2 months	>36 months	CHAR
Casting - Continuous Ca	Ladle free /oxygen opening	2-Medium (every few minutes)	2 months	>36 months	CHAR
Casting - Continuous Ca	Tundish preheating duration (min)	1-Low (once per hour)	2 months	>36 months	REAL
Casting - Continuous Ca	Tundish cover addition (kg)	2-Medium (every few minutes)	2 months	>36 months	REAL
Casting - Continuous Ca	Casting duration (min)	3-High (every few seconds)	2 months	>36 months	REAL
Casting - Continuous Ca	Position of cast in the casting sequence	2-Medium (every few minutes)	2 months	>36 months	CHAR
Casting - Continuous Ca	Ladle shroud inertisation	3-High (every few seconds)	2 months	>36 months	CHAR
Casting - Continuous Ca	Steel composition	2-Medium (every few minutes)	2 months	>36 months	CHAR
Casting - Continuous Ca	Clogging number	3-High (every few seconds)	2 months	>36 months	CHAR

From gathered information we can conclude that the retention period for uncompressed data is 2 months, after which it is transferred to long term storage infrastructure. Influence of the outage on model run is also very diverse and most of the process stages have at least one variable, which is critically important. Most of the variables have a high storing frequency (every few seconds).

3.1.4 Use Case 3: EIPC D2.6

UC3 addresses the definition of specifications and requirements related to quality of data and digitalization potential aspects of deployment of digital cognitive architecture in non-ferrous industrial case. [3]

Investment casting process is a complex manufacturing process, shown in Figure 9. This process is challenging, because the component or material condition is not known until final inspection and defects can happen in each of the phases. None of the traditional measures have shown success and it is with digital tools supported by artificial intelligence, that next opportunity to improve the process presents itself. [3]

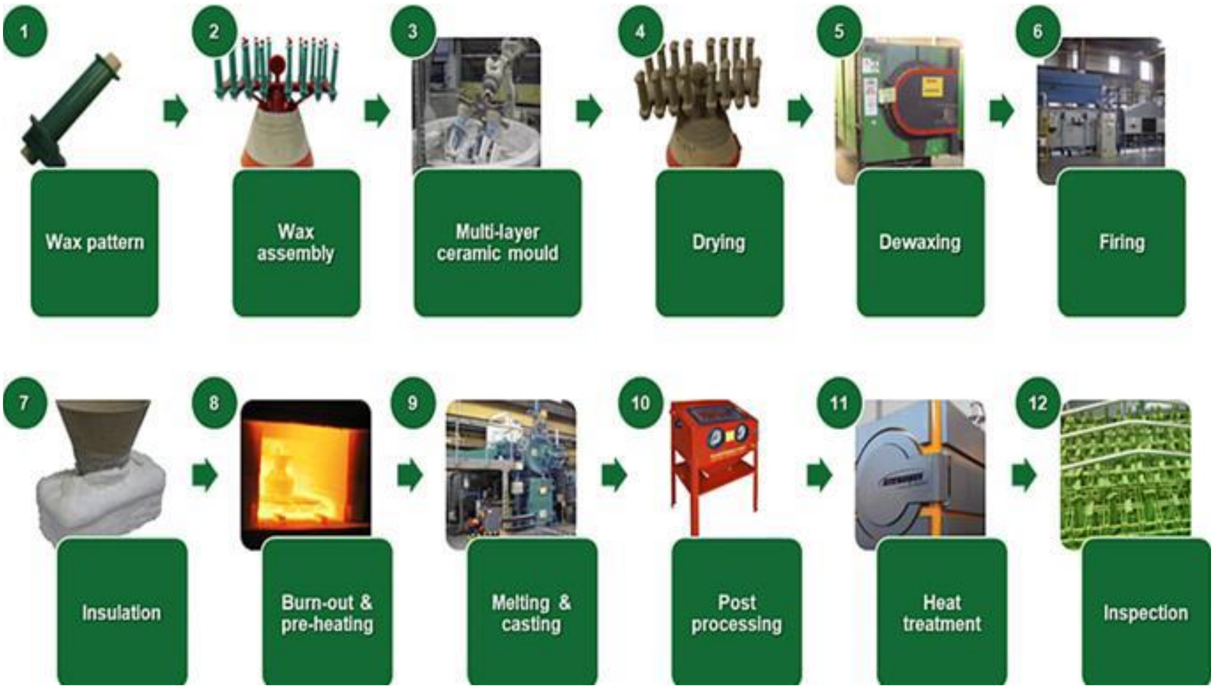

Figure 9 Main stages of investment casting process [3]

Digital infrastructure in this UC shall provide visualization of variable evolution in process stages in real time, providing basis for reaction and adaptation to deviations. Defects will be forecasted with help of predictive controls, and this will allow to correct the parameters before product failures will occur.

UC3 prepared an action plan to implement the digital infrastructure, which includes new hardware for the data storage, as well as improved data visualization in all process stages with custom made user interfaces - screens. [3]

Data is captured/stored in systems using one of the following methods:

- FactoryWin ERP solution
- EKIOM web platform
- MS Excel files with manual input for furnace aluminium shell building
- MS Access database for heat treatment
- Oxycomb sensors with modbus connectivity
- Shell building robots – MSSQL server

Methods are illustrated in Figure 10.

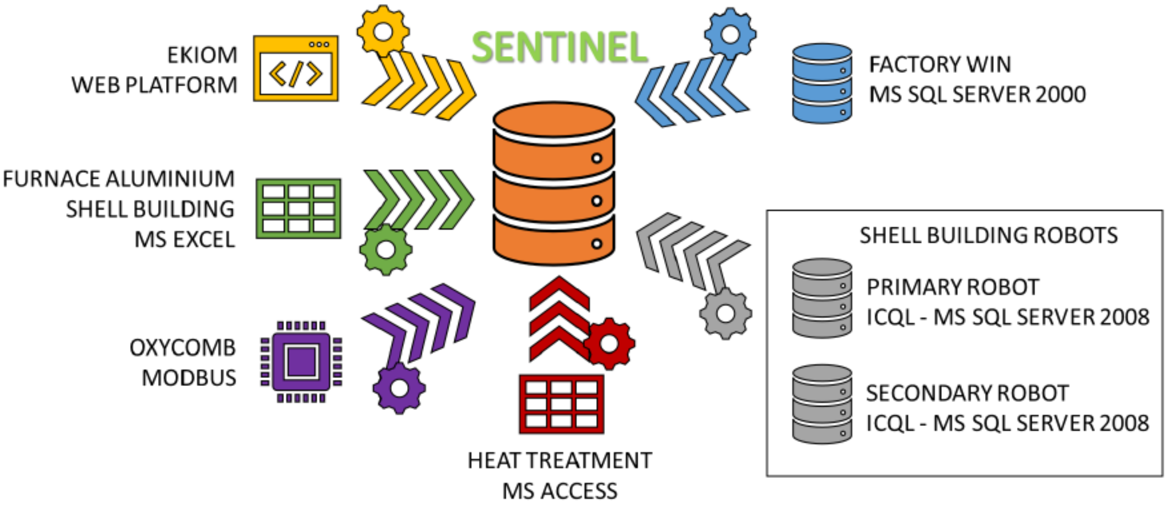

Figure 10 EIPC data infrastructure

Sentinel software from Salomon Metallurgy serves as analytic platform to aggregate and process the required data from diverse sources.

Gathering of additional attribute values

Based on [4] additional attribute values were collected as shown in Table 5.

Table 5 EIPC process variables with additional attributes defined in T5.1

Process stage	Variable	Source	Protocol	Target data type	Availability	Model evaluation impact	Model generation impact	Process impact	Agent acquisition ty	Storing frequency
Wax injection	Operator (part)	FactoryWin (ERP)	SQL server 2000	uint+nvarchar	Outage is not critical	No influence	Manual data errors	KPI - substantial	Database query	When a change is detected
Wax injection	Machine (part)	FactoryWin (ERP)	SQL server 2000	uint	<10 minutes	Model run cancelled	Manual data errors	No impact	Database query	When a change is detected
Wax injection	Downtimes (part)	FactoryWin (ERP)	SQL server 2000	datetime	Outage is not critical	No influence	Manual data errors	No impact	Database query	When a change is detected
Wax injection	Rejection rate (part)	FactoryWin (ERP)	SQL server 2000	decimal	<10 minutes	Reduced model accuracy	Manual data errors	No impact	Database query	When a change is detected
Wax injection	Time from injection to assembl	FactoryWin (ERP)	SQL server 2000	time	<10 minutes	Reduced model accuracy	Manual data errors	No impact	Database query	When a change is detected
Wax assembly	Operator (assembly)	FactoryWin (ERP)	SQL server 2000	uint+nvarchar	Outage is not critical	No influence	Manual data errors	KPI - marginal	Database query	When a change is detected
Wax assembly	Rejection rate	FactoryWin (ERP)	SQL server 2000	decimal	<10 minutes	Reduced model accuracy	Manual data errors	No impact	Database query	When a change is detected
Wax assembly	Time from assembly to shell ro	FactoryWin (ERP)	SQL server 2000	time	<10 minutes	Reduced model accuracy	Manual data errors	No impact	Database query	When a change is detected
Wax assembly	Room temperature	EKIOM web	Https + JSON	decimal	<1 hour	Reduced model accuracy	Sensor errors	No impact	HTTPS request	15 minutes
Wax assembly	Operator (final assembly)	FactoryWin (ERP)	SQL server 2000	uint+nvarchar	Outage is not critical	No influence	Manual data errors	KPI - marginal	Database query	When a change is detected
Shell building	Viscosity of primary colloidal si	FactoryWin (ERP)	SQL server 2000	decimal	<1 hour	Reduced model accuracy	Manual data errors	KPI - substantial	Database query	When a change is detected
Shell building	Refractory primary slurry	FactoryWin (ERP)	SQL server 2000	decimal	<1 hour	Reduced model accuracy	Manual data errors	KPI - substantial	Database query	When a change is detected
Shell building	% Colloidal silica primary bath	FactoryWin (ERP)	SQL server 2000	decimal	<1 hour	Reduced model accuracy	Manual data errors	KPI - substantial	Database query	When a change is detected
Shell building	Gelification primary slurry	FactoryWin (ERP)	SQL server 2000	decimal	<1 hour	Reduced model accuracy	Manual data errors	KPI - substantial	Database query	When a change is detected
Shell building	Fungus and bacteria primary	FactoryWin (ERP)	SQL server 2000	decimal	<1 hour	Reduced model accuracy	Manual data errors	KPI - substantial	Database query	When a change is detected
Shell building	Time from renewal of tank prir	FactoryWin (ERP)	SQL server 2000	time	<1 hour	Reduced model accuracy	Manual data errors	KPI - marginal	Database query	When a change is detected
Shell building	Time from refeeding of tank pr	FactoryWin (ERP)	SQL server 2000	time	<1 hour	Reduced model accuracy	Manual data errors	KPI - marginal	Database query	When a change is detected
Shell building	Drying time between layers pri	VATECH Robot	SQL server 2008	time	<10 minutes	Reduced model accuracy	None	KPI - substantial	Database query	When a change is detected
Shell building	Shell room temperature range	EKIOM web	Https + JSON	decimal	<1 hour	Reduced model accuracy	Sensor errors	KPI - substantial	HTTPS request	15 minutes
Shell building	Shell room maximum tempera	EKIOM web	Https + JSON	decimal	<1 hour	Reduced model accuracy	Sensor errors	KPI - substantial	HTTPS request	15 minutes
Shell building	Shell room minimum temperat	EKIOM web	Https + JSON	decimal	<1 hour	Reduced model accuracy	Sensor errors	KPI - substantial	HTTPS request	15 minutes
Shell building	Shell room average temperatu	EKIOM web	Https + JSON	decimal	<1 hour	Reduced model accuracy	Sensor errors	KPI - substantial	HTTPS request	15 minutes
Shell building	Downtimes primary	FactoryWin (ERP)	SQL server 2000	datetime	<1 hour	Reduced model accuracy	Manual data errors	No impact	Database query	When a change is detected
Shell building	Total time in primary	VATECH Robot	SQL server 2008	time	<10 minutes	Reduced model accuracy	None	No impact	Database query	When a change is detected
Shell building	Viscosity of back up colloidal si	FactoryWin (ERP)	SQL server 2000	decimal	<1 hour	Reduced model accuracy	Manual data errors	KPI - substantial	Database query	When a change is detected
Shell building	Refractory back up slurry	FactoryWin (ERP)	SQL server 2000	decimal	<1 hour	Reduced model accuracy	Manual data errors	KPI - substantial	Database query	When a change is detected
Shell building	% Colloidal silica back up bath	FactoryWin (ERP)	SQL server 2000	decimal	<1 hour	Reduced model accuracy	Manual data errors	KPI - substantial	Database query	When a change is detected
Shell building	Gelification back up	FactoryWin (ERP)	SQL server 2000	decimal	<1 hour	Reduced model accuracy	Manual data errors	KPI - substantial	Database query	When a change is detected
Shell building	Fungus and bacteria back up	FactoryWin (ERP)	SQL server 2000	decimal	<1 hour	Reduced model accuracy	Manual data errors	KPI - substantial	Database query	When a change is detected
Shell building	Time from renewal of tank bac	FactoryWin (ERP)	SQL server 2000	time	<1 hour	Reduced model accuracy	Manual data errors	KPI - marginal	Database query	When a change is detected
Shell building	Time from refeeding of tank ba	FactoryWin (ERP)	SQL server 2000	time	<1 hour	Reduced model accuracy	Manual data errors	KPI - marginal	Database query	When a change is detected
Shell building	Drying time between layers ba	VATECH Robot	SQL server 2008	time	<10 minutes	Reduced model accuracy	None	KPI - substantial	Database query	When a change is detected
Shell building	Shell room temperature range	EKIOM web	Https + JSON	decimal	<1 hour	Reduced model accuracy	Sensor errors	KPI - substantial	HTTPS request	15 minutes
Shell building	Shell room maximum tempera	EKIOM web	Https + JSON	decimal	<1 hour	Reduced model accuracy	Sensor errors	KPI - substantial	HTTPS request	15 minutes
Shell building	Shell room minimum temperat	EKIOM web	Https + JSON	decimal	<1 hour	Reduced model accuracy	Sensor errors	KPI - substantial	HTTPS request	15 minutes
Shell building	Shell room average temperatu	EKIOM web	Https + JSON	decimal	<1 hour	Reduced model accuracy	Sensor errors	KPI - substantial	HTTPS request	15 minutes
Shell building	Downtimes back up	FactoryWin (ERP)	SQL server 2000	datetime	<1 hour	Reduced model accuracy	Manual data errors	No impact	Database query	When a change is detected
Shell building	Total time in back up	VATECH Robot	SQL server 2008	time	<10 minutes	Reduced model accuracy	None	KPI - marginal	Database query	When a change is detected
Shell building	Drying time	FactoryWin (ERP)	SQL server 2000	time	<10 minutes	Reduced model accuracy	Manual data errors	No impact	Database query	When a change is detected
Shell building	Total time shell room	Calculated using other data	N/A - Calculated in target	time	Undefined (development)	Undefined (development)	Undefined (development)	No impact	None	When a change is detected
Shell building	PH primary	FactoryWin (ERP)	SQL server 2000	decimal	<1 hour	Reduced model accuracy	Manual data errors	KPI - substantial	Database query	When a change is detected
Shell building	PH back up	FactoryWin (ERP)	SQL server 2000	decimal	<1 hour	Reduced model accuracy	Manual data errors	KPI - substantial	Database query	When a change is detected
Shell building	Density primary bath	FactoryWin (ERP)	SQL server 2000	decimal	<1 hour	Reduced model accuracy	Manual data errors	KPI - substantial	Database query	When a change is detected
Shell building	Density primary slurry	FactoryWin (ERP)	SQL server 2000	decimal	<1 hour	Reduced model accuracy	Manual data errors	KPI - substantial	Database query	When a change is detected
Shell building	Density back up bath	FactoryWin (ERP)	SQL server 2000	decimal	<1 hour	Reduced model accuracy	Manual data errors	KPI - substantial	Database query	When a change is detected
Shell building	Density back up slurry	FactoryWin (ERP)	SQL server 2000	decimal	<1 hour	Reduced model accuracy	Manual data errors	KPI - substantial	Database query	When a change is detected
Shell building	Maximum humidity in primary	EKIOM web	Https + JSON	decimal	<1 hour	Reduced model accuracy	Sensor errors	KPI - substantial	HTTPS request	15 minutes
Shell building	Minimum humidity in primary	EKIOM web	Https + JSON	decimal	<1 hour	Reduced model accuracy	Sensor errors	KPI - substantial	HTTPS request	15 minutes
Shell building	Humidity variation range in pri	EKIOM web	Https + JSON	decimal	<1 hour	Reduced model accuracy	Sensor errors	KPI - substantial	HTTPS request	15 minutes
Shell building	Average humidity in primary	EKIOM web	Https + JSON	decimal	<1 hour	Reduced model accuracy	Sensor errors	KPI - substantial	HTTPS request	15 minutes
Shell building	Maximum humidity in back up	EKIOM web	Https + JSON	decimal	<1 hour	Reduced model accuracy	Sensor errors	KPI - substantial	HTTPS request	15 minutes
Shell building	Minimum humidity in back up	EKIOM web	Https + JSON	decimal	<1 hour	Reduced model accuracy	Sensor errors	KPI - substantial	HTTPS request	15 minutes
Shell building	Humidity variation range in bac	EKIOM web	Https + JSON	decimal	<1 hour	Reduced model accuracy	Sensor errors	KPI - substantial	HTTPS request	15 minutes
Shell building	Average humidity in back up	EKIOM web	Https + JSON	decimal	<1 hour	Reduced model accuracy	Sensor errors	KPI - substantial	HTTPS request	15 minutes
Shell building	Operator blowing moulds in pr	FactoryWin (ERP)	SQL server 2000	uint+nvarchar	Outage is not critical	No influence	Manual data errors	KPI - substantial	Database query	When a change is detected
Shell building	Operator that download the m	FactoryWin (ERP)	SQL server 2000	uint+nvarchar	Outage is not critical	No influence	Manual data errors	KPI - substantial	Database query	When a change is detected
Dewaxing	Operator (dewaxing)	FactoryWin (ERP)	SQL server 2000	uint+nvarchar	Outage is not critical	No influence	Manual data errors	No impact	Database query	When a change is detected
Pouring	Preheating temperature	EKIOM web	Https + JSON	decimal	<1 hour	Reduced model accuracy	Sensor errors	No impact	HTTPS request	15 minutes
Firing	Number of furnace	FactoryWin (ERP)	SQL server 2000	uint	<10 minutes	Model run cancelled	Manual data errors	No impact	Database query	When a change is detected
Firing	Time in the furnace	EKIOM web	Https + JSON	time	<1 hour	Reduced model accuracy	Sensor errors	No impact	HTTPS request	15 minutes
Firing	Operator	FactoryWin (ERP)	SQL server 2000	uint+nvarchar	Outage is not critical	No influence	Manual data errors	No impact	Database query	When a change is detected
Melting	Temperature of metal (alumini	Furnace Excel	Excel reader	decimal	<1 hour	Reduced model accuracy	Manual data errors	No impact	Excel data reader	When a change is detected
Melting	Degree of modification (alumir	Furnace Excel	Excel reader	decimal	<1 hour	Reduced model accuracy	Manual data errors	No impact	Excel data reader	When a change is detected
Melting	Chemical composition (alumin	Furnace Excel	Excel reader	decimal[]	<1 hour	Reduced model accuracy	Manual data errors	No impact	Excel data reader	When a change is detected
Melting	Shift (aluminium)	Furnace Excel	Excel reader	uint+nvarchar	Outage is not critical	No influence	Manual data errors	No impact	Excel data reader	When a change is detected
Melting	Day of melting (aluminium)	Furnace Excel	Excel reader	date	Outage is not critical	No influence	Manual data errors	No impact	Excel data reader	When a change is detected
Melting	Hour of melting (aluminium)	Furnace Excel	Excel reader	time	Outage is not critical	No influence	Manual data errors	No impact	Excel data reader	When a change is detected
Melting	Shift (steel)	FactoryWin (ERP)	SQL server 2000	uint+nvarchar	Outage is not critical	No influence	Manual data errors	No impact	Database query	When a change is detected
Melting	Day of melting (steel)	FactoryWin (ERP)	SQL server 2000	date	Outage is not critical	No influence	Manual data errors	No impact	Database query	When a change is detected
Melting	Hour of melting (steel)	FactoryWin (ERP)	SQL server 2000	time	Outage is not critical	No influence	Manual data errors	No impact	Database query	When a change is detected
Melting	Downtimes (steel)	FactoryWin (ERP)	SQL server 2000	datetime	<1 hour	Reduced model accuracy	Manual data errors	No impact	Database query	When a change is detected
Melting	Chemical composition (superal	FactoryWin (ERP)	SQL server 2000	decimal[]	<1 hour	Reduced model accuracy	Manual data errors	No impact	Database query	When a change is detected
Melting	Shift (superalloys)	FactoryWin (ERP)	SQL server 2000	uint+nvarchar	Outage is not critical	No influence	Manual data errors	No impact	Database query	When a change is detected
Melting	Day of melting (superalloys)	FactoryWin (ERP)	SQL server 2000	date	Outage is not critical	No influence	Manual data errors	No impact	Database query	When a change is detected
Melting	Hour of melting (superalloys)	FactoryWin (ERP)	SQL server 2000	time	Outage is not critical	No influence	Manual data errors	No impact	Database query	When a change is detected
Melting	Downtimes (superalloys)	FactoryWin (ERP)	SQL server 2000	datetime	<1 hour	Reduced model accuracy	Manual data errors	No impact	Database query	When a change is detected
Melting	Number of degassing operatio	Furnace Excel	Excel reader	uint	<1 hour	Reduced model accuracy	Manual data errors	KPI - substantial	Excel data reader	When a change is detected
Melting	Refining level of aluminium	Furnace Excel	Excel reader	decimal	<1 hour	Reduced model accuracy	Manual data errors	No impact	Excel data reader	When a change is detected
Pouring	Operator	FactoryWin (ERP)	SQL server 2000	uint+nvarchar	Outage is not critical	No influence	Manual data errors	No impact	Database query	When a change is detected
Finishing	Penetrant testing	FactoryWin (ERP)	SQL server 2000	bit	<4 hours	Reduced model accuracy	Manual data errors	Process halted	Database query	When a change is detected
Finishing	X-Ray testing	FactoryWin (ERP)	SQL server 2000	bit	<4 hours	Reduced model accuracy	Manual data errors	Process halted	Database query	When a change is detected
Finishing	Operator	FactoryWin (ERP)	SQL server 2000	uint+nvarchar	Outage is not critical	No influence	Manual data errors	KPI - substantial	Database query	When a change is detected
Firing	Operator of prefiring	FactoryWin (ERP)	SQL server 2000	uint+nvarchar	Outage is not critical	No influence	Manual data errors	KPI - substantial	Database query	When a change is detected
Firing	Prefiring temperature	EKIOM web	Https + JSON	decimal	<1 hour	Reduced model accuracy	Sensor errors	KPI - substantial	HTTPS request	15 minutes
Firing	Position	FactoryWin (ERP)	SQL server 2000	uint	<1 hour	Reduced model accuracy	Manual data errors	KPI - substantial	Database query	When a change is detected

From the gathered additional attributes, we can conclude the following:

- There is lots of communication with older DB systems, that have reached end of extended support (MS SQL 2000 server SP4 has reached end of extended support on April 9, 2013)
- There are few variables with very high availability target (<10 minutes outage). Most of the variables have moderate availability target (<1 hour).
- Most of the process variables have moderate impact on model evaluation – reduced model accuracy
- Most of the errors related to model generation stem from manual data input.
- Impact on process is mostly either substantial or no impact. Other values are quite rare, but a few are critical, in the area of Finishing – Testing.

- Data acquisition is mostly based on DB queries and the storage frequency is related to detection of change.

3.2 *Specific recommendations for use cases*

Findings of the UC analysis provided information on data infrastructure strategy and the approach to digital infrastructure implementation. Taking these findings as a basis, expert knowledge related to standards and current industry approaches to digital infrastructure was applied for UC specific recommendations.

Recommendations are to be taken as a reference point for further improvement and data infrastructure enhancements.

3.2.1 UC1: SIJ Acroni

SIJ Acroni is currently deploying industrial cloud-based infrastructure, part of which is the Edge computing platform. Both EAF and ZRM use cases will be supported by this infrastructure, which will integrate into existing data infrastructure, based on MES with Oracle DB and IBA system with OPC/UA interface. Shown in Figure 4 and Figure 5.

The Solution that is being deployed, is based on industrial standards regarding cybersecurity, namely IEC 62443-4-1 standard. It is recommended that:

- Additional development is made adhering to development practices outlined in the IEC 62443-4-1 [6].
- Edge device is integrated into existing cloud infrastructure, thus being part of the ecosystem, as defined in IEC 62443 chapters 2-1 and 3-2. Care should be placed on sufficient security countermeasures, as identified by [11].
- Regular risk assessments and maintenance activities shall be performed on Edge device, to ensure security compliance and control the residual risk.
- Communication partners of the Edge device shall have at least same level security requirements in place, as there are on Edge device.
- MES system database shall have appropriate security controls in place.
- Production data that will be uploaded to cloud-based storage shall have defined storage lifetime, or policies regarding storage space management shall be in place, to avoid storage congestions.

3.2.2 UC2: Sidenor and Voestalpine

Both partners in UC2 reported very high levels of data storage capabilities and functionality and no immediate possibilities for improvement could be identified. Some general recommendations can however be made:

- Oversight on product type and instance lifetimes, as covered in IEC 62890 standard [12]. To ensure continued stability and security of the product instances, e.g., machinery and production lines, they need to be regularly updated and serviced. Using out-of-support systems could introduce risks, related to cybersecurity.
- Development of add-ons and software enhancements shall be made using good development practices, specifically related to IEC 62443-4-1. [6]
- Systems and equipment, that make up the digitalization infrastructure shall be regularly reviewed according to IEC 62443 [13] [11], to control the risks, related to data protection.

3.2.3 UC3: Eibar Precision Casting

UC3 is focusing on the use of special purpose AI augmented software, supported by agents to collect the process data from various systems and data sources. Sentinel software by Solomon Metallurgy will be used for analysis of data and it will be fed by information from different data sources. Based on available data, some recommendations are possible:

- Unified management standards and policies for different data sources. Adherence to standards such as IEC 62443-3-2 and IEC 62443-3-3 would simplify data management.
- Actions shall be taken, such as user training or awareness training, to minimize the possibility of human error. This is important because of large number of manual data entry points.
- FactoryWin ERP is running in an unsecure environment, due to fact, that MS SQL 2000 server is out of extended support. Special attention shall be paid to implementing security measures, such as whitelisting, or segmentation, to minimize impact in case of security incident, regardless of any future planned upgrades. Backup and restore procedures shall be in place and regularly verified.
- Shell building robots are using an out of support MS SQL version. With MS SQL 2008, more functions are available, compared to MS SQL 2000, as well as security options. Nevertheless, same recommendations apply as for other MS SQL versions that are out of support.
- Database hardening can be supported by publicly available documents, related to this topic. One such example is Center for Internet Security Benchmarks. [14]

4 Conclusion

This document represents the deliverable D5.3: “Preparation of design principles for the data infrastructure” in the framework of the SPIRE project entitled “Optimization and performance improving in metal industry by digital technologies” (Project Acronym: INEVITABLE; Grant agreement no.: 869815).

Through work done on this document, practical experience from consulting projects was combined with scientific data and research papers on topic of Industry 4.0 and State of the Art it can be concluded, that digital data infrastructure shall be a part of a larger effort, based on the assessment of organizational maturity and digital strategy. As such, it is based on organizations maturity and the current state of digitalization.

From analysis of digital state of the art in the partner organizations we see that each has different approach, yet they are on approximately same maturity level. Differences in approaches becomes even more evident, as wider industry landscape is taken into account and a myriad of different methodologies complicates the digitalization effort. It is therefore a good practice to use frameworks that build on previous successful projects, as well as enable comparison of organizations’ progress to the best in class. Frameworks such as Smart Industry Readiness Index have so far shown promise in starting the digital further research shall be done in direction of preparation of best practice approaches to use the methodology in industrial organizations. [4] [15]

5 *Bibliography*

[1] V. Logar, M. Glavan, D. Gradišar and M. Loncnar, *Final requirements & specifications for Use case 1: Implementation of the EAF and ZRM optimization*, Inevitable project, 2021.

[2] B. Palm and B. Kleimt, *Final requirements & specifications for Use case 2: Smart sensor and model-based decision support system for ultra clean steel production*, Inevitable project, 2021.

[3] A. González and F. Santos, *Final requirements & specifications for Use case 3: Deployment of digital cognitive architecture in nonferrous industrial case*, Inevitable project, 2021.

[4] M. Demšar, *Consolidated set of requirements*, Inevitable project, 2020.

[5] Science Direct, "ScienceDIrect," 09 08 2021. [Online]. Available: https://www.sciencedirect.com/topics/computer-science/waterfall-methodology.

[6] IEC, *IEC 62443-4-1: Security for Industrial Automation and Control Systems, Part 4-1:Secure product development lifecycle requirements*, IEC, 2018.

[7] *IEC 62443-4-2: Security for Industrial Automation and Control Systems, Part 4-2: Technical security requirements for IACS components*, IEC, 2019.

[8] B. Palm and B. Kleimt, *Final requirements & specifications for Use case 2: Smart sensor and model-based decision support system for ultra clean steel production*, Inevitable project, 2021.

[9] M. Demšar, *D5.1: Consolidated set of requirements*, INEVITABLE Project, 2020.

[10] M. Demšar, *D5.2: Preparation of design principles for the communication infrastructure*, INEVITABLE Project, 2021.

[11] IEC, *IEC 62443-3-3: Security for Industrial Automation and Control Systems, Part 3-3: System security requirements and security levels*, IEC, 2013.

[12] *IEC 62890: Industrial-process measurement, control and automation – Life-cyclemanagement*, IEC, 2020.

[13] IEC, *IEC 62443-3-2: Security for industrial automation and control systems, Part 3-2: Security risk assessment for system design*, IEC, 2020.

[14] Center for Internet Security: *CIS Benchmarks*, [Online]. Available: https://www.cisecurity.org/cis-benchmarks/. [Accessed 16 9 2021].

[15] Singapore Economic Development Board, *Smart Industry Readiness Index*, 13 7 2020. [Online]. Available: https://www.siri.gov.sg/. [Accessed 4 10 2021].