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ENERGY-AWARE FACTORY ANALYTICS FOR PROCESS INDUSTRIES

Deliverable D7.3

Cognitive Transformation report (Interim Version)

Version 1.2	**Lead Partner** PIA
Date 25/10/2023	**Project Name** FACTLOG – Energy-aware Factory Analytics for Process Industries

FACTLOG has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 869951

Call Identifier
H2020-NMBP-SPIRE-2019

Topic
DT-SPIRE-06-2019 - Digital technologies for improved performance in cognitive production plants

Project Reference
869951

Start date
November 1st, 2019

Type of Action
IA – Innovation Action

Duration
42 Months

Dissemination Level

X	**PU**	Public
	CO	Confidential, restricted under conditions set out in the Grant Agreement
	CI	Classified, information as referred in the Commission Decision 2001/844/EC

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Executive Summary

In the first half of the FACTLOG project, the main focus was the implementation of modules and applications to enable digital twinning functionalities within industrial contexts. To make this happen, the requirements, use cases and KPIs defined in WP1 guided the implementation and integration of these modules.

As the whole project is designed over two development cycles, the focus in this intermediate step was on the integration of significant pilot demonstrations, in order to collect initial results that could lead to improvements in subsequent developments.

Furthermore, it was considered necessary to focus this phase on the creation of methodologies that are as shared and standardised as possible in order to

- Evaluate end-user feedback in a structured way
- Evaluate the relevance of some KPIs defined at the beginning of the project (or even before its inception) against the concrete developments of the technical work and the progress of the State of the Art

This document reports the status of the pilots' implementation after the first project cycle, and the methodologies and indicators used for their evaluation.

Being an interim report, this document focuses on the methodological aspects, which are also fundamental for the second cycle in order to have comparable techniques available, and on subjective aspects, such as the relevance of the functions enabled by the platform and aspects of usability of the interface.

To do this, workshops were organised involving the main stakeholders of the pilots to gather their impressions and guide the development of the technologies in the next steps.

This document is closely linked to deliverable D7.5, in which the results of the workshops are reported.

After a first part focused on methodological aspects, which are valid for this first cycle but will also form the basis for the final evaluation cycle, the document presents a brief overview of the situation of each pilot, both in terms of implementation and expected benefits.

The document will be updated with the results of the final evaluation through the D7.4, planned for M40.

Revision History

Revision	Date	Description	Organisation
0.1	15/05/2021	First version of Table of Contents	PIA, DOM
0.2	28/06/2021	Feedback on ToC	MAG
0.3	10/06/2021	Updated version of ToC	PIA, DOM
0.5	17/09/2021	First round of contributions	DOM, PIA, BRC
0.7	06/10/2921	Second round of contributions	Pilot owners
0.8	07/10/2021	Deliverable ready for internal review	PIA, DOM
0.9	11/10/2021	Internal review	MAG, EPFL
1.0	15/10/2021	Deliverable ready for submission	PIA, DOM
1.2	25/10/2023	Addressing the comments from EC	MAG

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1 Introduction

1.1 Purpose and Scope

The scope of this document is to report the status of the pilots' implementation, and the methods and criteria used for the evaluation of the FACTLOG ecosystem within the industrial contexts. The document will focus on the methodological aspects, will refer to the set-up of the pilots and the workshops performed to evaluate the implementation.

1.2 Relation with other Deliverables

This document uses as a main input the use cases and the KPIs defined in D1.1 and D1.2, and further refined in following deliverables, such as D7.1. The document will also refer to D6.5 regarding the status of the integrated package and the common architecture, used as a reference for the implementation of each pilot. Additionally, this document also refers to the overall validation strategy, distinguishing functional aspects covered in WP6 and non-functional ones, that are part of WP7.

Moreover, the document will be an input for D7.5, where the results of the workshops will be reported, and for D7.4, where the final description of this task will be provided, the methodology will be further refined and updated if needed, and the results will be compared among the two cycles.

1.3 Structure of the Document

Besides the introductions, the document is structured as follows:

- **Chapter 2** describes the **Common Evaluation Framework**, i.e., the common approach to the assessment used among the different pilots. It will also describe the instantiation of the methodology for this cycle and will provide descriptions of the methodologies and tools used for the evaluation.
- The other chapters describe **the implementation of each pilot**, referring to pilot status, the test scenarios, the expected benefits of FACTLOG in the specific pilot cases and the set-up of the workshops for the first evaluation. Specifically:
  - **Chapter 3** refers to JEMS pilot[1]
  - **Chapter 4** refers to TUPRAS pilot
  - **Chapter 5** refers to PIA pilot
  - **Chapter 6** refers to CONT pilot
  - **Chapter 7** refers to BRC pilot
- **Chapter 8** reports some first conclusions, and especially an outlook on the next steps expected for this task and for the related activities.
- In **Annex A,** the questionnaires used in this cycle are reported.

[1] JEMS pilot did not meet its objectives, especially with regards to the integration of the FACTLOG system to its plant since there is not yet an operative plant in Slovenia.

2 Common Evaluation Framework

In this chapter, the Common Evaluation framework is presented. The path towards the evaluation process as well as the tools and methodologies are described. Additionally, a shortened reference to the FACTLOG architecture is provided, in order to refer the actual instantiation of the pilots to the common reference architecture of the project.

2.1 FACTLOG approach to the evaluation of the pilots

In FACTLOG, a common approach to the pilots' implementation and evaluation has been followed. In this task, the pilots have realized the scenarios defined in WP1, and developed the proof-of-concept demonstration of the FACTLOG platform in their test cases.

Given the overall project structure, which is based on two development cycles with an intermediate evaluation stage, the demonstrations performed at this stage (which is just after the mid of the project duration) refers to an intermediate version of the platform itself.

Each pilot focused on different aspects (e.g., concentrating, during the first cycle, on specific modules or on transitional versions of each module), and set up a first integrated package of their industrial case.

Similarly, from a system evaluation point of view, the activities have been planned following two cycles: as reported in Figure 1, the first evaluation cycle has been intended to focus on the assessment of the relevance of the **features implemented in the pilots**, as well as on the confirmation of the **relevance of the selected scenarios and KPIs**. Additionally, specific evaluations on **Human-Machine Interaction aspects** have been planned to be conducted in this cycle.

On the other hand, the second evaluation cycle (planned after the third year of the project, on the final version of the integrated platform) will focus on the technical evaluation of the system performance and KPIs (e.g., actual improvements of plant efficiency, reduction of costs etc.) as well as on the quantitative analysis of financial impact on the industrial cases.

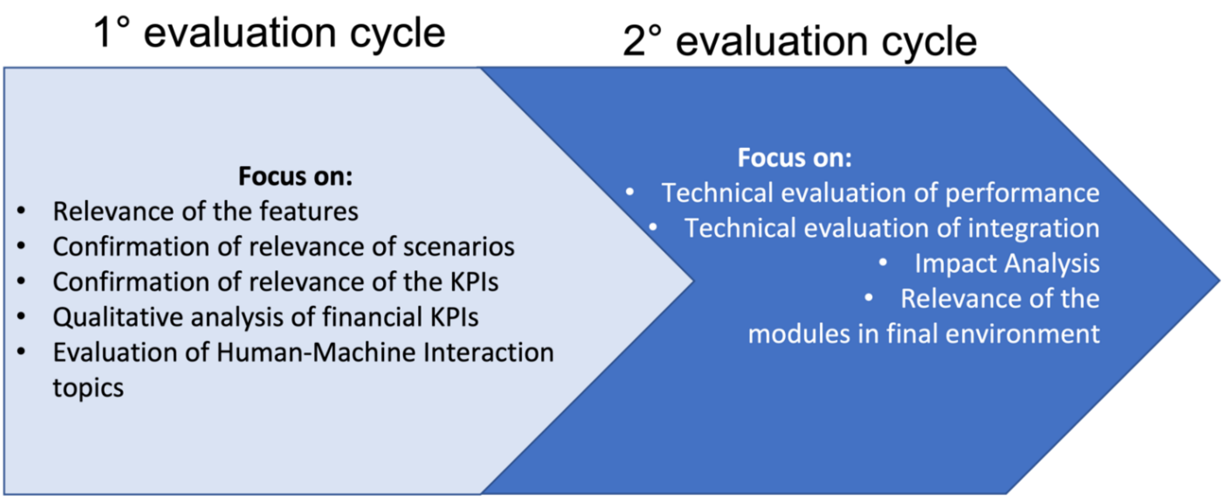

Figure 1: FACTLOG evaluation approach based on project cycles

Given that the overall FACTLOG system is implemented only at an intermediate step, in the first evaluation cycle the KPIs reported in the DOA (and refined and further analysed in WP1, and in D1.2 in particular) will be considered only from a qualitative point of view, i.e., to check if the technical development will confirm that the indicators are still:

- **Relevant**
- **Realistic** and
- **Measurable**

Additional details on the overall methodology and its implementation in this cycle are reported in Chapter 2.3.

2.2 FACTLOG System Architecture

The common starting point for the implementation of the FACTLOG pilots has been the common reference architecture, iteratively refined up to the most updated version described in D6.5 “Integrated Package and Platform – Interim Version”.

The FACTLOG architecture consists of various functional blocks, that enable a set of services able to foster the implementation of planning and control through the combination of knowledge-based models and operational models. The system is fed by pseudo real-time as well as historical data, depending on the service.

The building blocks that compose the FACTLOG platform are:

- The **Analytics Module**, which has the role of detecting anomalies, and performing predictions and situation analysis
- The **Process and Simulation Modelling framework**, which includes all methods, algorithms, services and tools that allow the representation of the static as well as the dynamic structure of the system.
- The **Optimization module**, that provides decision makers with information towards efficient scheduling and responding to problematic events that may arise in their everyday operations.
- The **Knowledge Graphs**, that refer to the ontologies to define the meaning of data and to model the FACTLOG domain at an abstract level.

The interoperation of services is enabled by the **Message and Service Bus (MSB)**, which has the role of allowing the communication and orchestration of data streams among the modules and from / to external data sources. The access to the services is enabled by the **Digital Twins platform**.

This architecture is depicted in Figure 2.

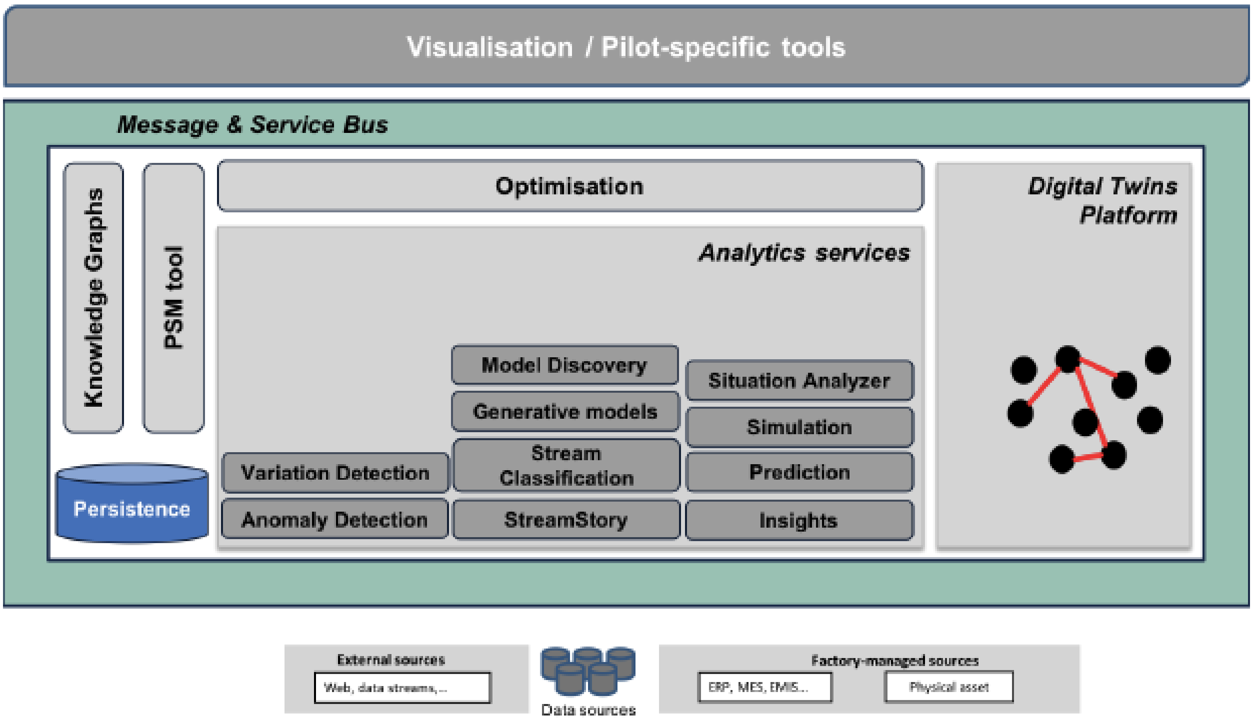

Figure 2: FACTLOG architecture

Starting from this common reference, all the pilots have instantiated their own implementation to keep only the modules relevant for the Use Cases identified in the early project phase.

At this stage of the project, the implementation of the pilots is at an intermediate step, meaning that most of the technical implementations are related to a preliminary version of the features (and/or to a development based on a partial sample of data). Additionally, some of the functionalities (e.g., Analytics module for PIA case) are currently developed as standalone module, but not yet integrated in the platform.

In Figure 3 it is reported the mapping between the applications and the pilot sites.

Features	Pilots				
	PIA	JEMS	BRC	TUPRAS	CONTI
Data Ingestion					
Digital Twins					
Analytics	First version, to be integrated in the next release				
Optimization		N / A			
Simulation	N / A	N / A			

Figure 3: Mapping of the pilot implementation after the first project cycle

In this picture, the knowledge graph has been included in the “Digital Twin” feature, since it is not a stand-alone module, but rather a service capable of enabling gaps in the functions of Enhanced Cognitive Twinning. During the 2nd iteration, the Knowledge Graphs are expected also to support some additional aspects of the cognition process. The Data Ingestion feature refers to the process of extraction and communication of data from / to the plant and the machineries.

In the update of this document (D7.4, planned for M40), the disparity between the current and the final implementation, including the mapping between the application and the pilots, will also be highlighted.

2.3 Common methodological framework

To implement a common approach to the pilots’ evaluation, a Common Evaluation Framework has been established. This approach allowed to have comparable results among the pilots, as well as a clear awareness of the evaluation steps and methodologies. Moreover, it also ensured a method to track all the KPIs defined in D1.2 and to guarantee that appropriate methods to evaluate them were considered.

The Common Evaluation Framework adopted in FACTLOG consists in using, where possible:

- A common understanding on the **evaluation phases**, in order to collect coherent results among all the pilots
- A strong **collaboration** in the definition of the KPIs and all other relevant indicators and methods that are the **object of the evaluation** of the system
- The use, where possible, of the same **MTT – Methodologies, Tools and Techniques**, (e.g., questionnaires, simulation methods, workshops modalities) to measure the same indicators

This evaluation approach divides the assessment phase in 3 macro categories:

1. **End users’ subjective evaluations:** they have been performed through dedicated workshops involving the pilots’ end users as well as technical partners, and were aimed at measuring subjective criteria, mostly related to the functionalities of the platform in the industrial context, the added value provided by the applications and User Interface topics, such as Usability and Acceptability.
2. **System performance evaluation:** aimed at measuring the technical performance of the FACTLOG ecosystem, through the evaluation of the single modules and their impact on the industrial test cases (mainly considered in the validation process of WP6, where tests at technology level will be performed).
3. **Impact evaluation:** performed through questionnaires and objective evaluations, to appraise the concrete impact of the project results on the pilot cases and tailor the exploitation strategies around these results.

An overall schematic picture of the proposed Common Evaluation Framework is proposed in Figure 4.

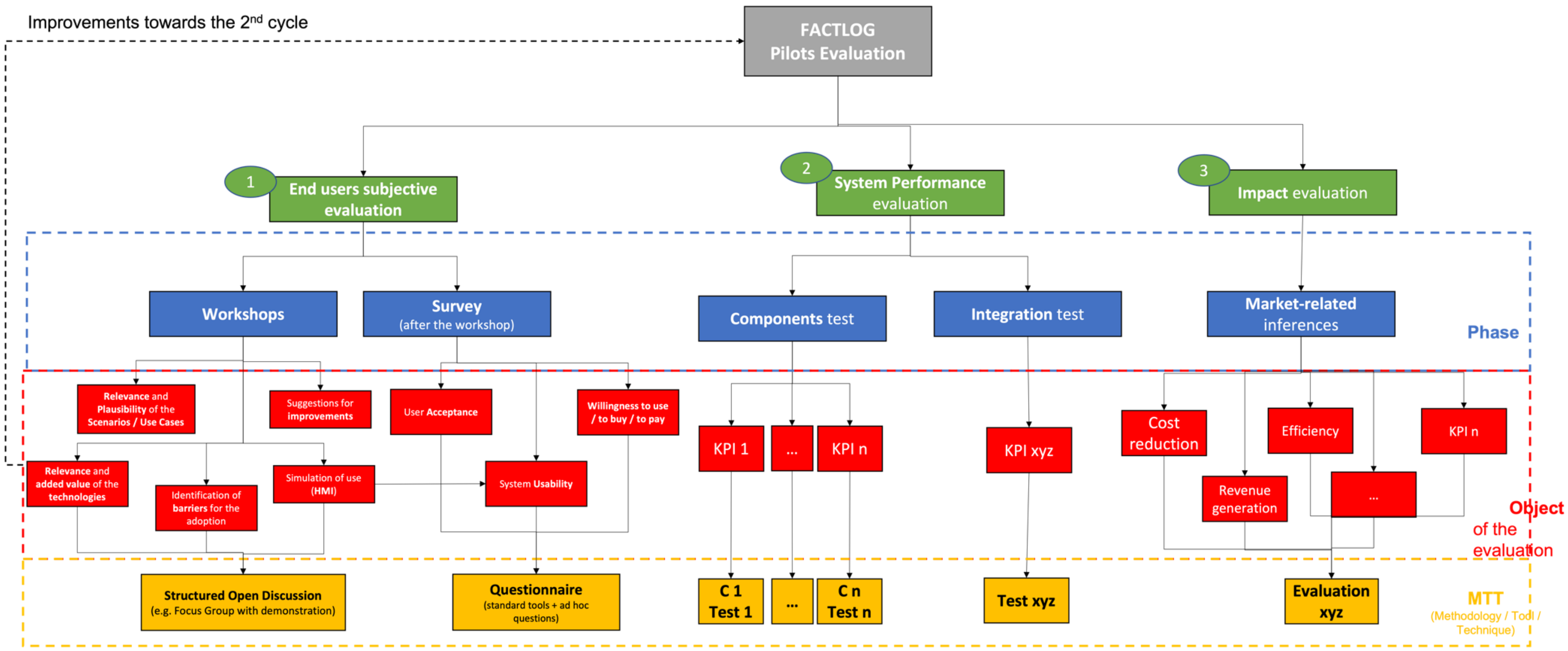

Figure 4: FACTLOG Common Evaluation Framework

As already stated, in the first iteration, only a partial implementation of the overall FACTLOG functionalities is performed and the first step of the overall assessment process is executed.

For this reason, this evaluation cycle focused mostly on the first assessment category, and partially on measuring, though a qualitative approach, the relevance of the indicators that are part of the third assessment category. Concerning the subjective perception of the end users, in this cycle, dedicated demonstrations have been performed involving both partners involved in the development and other relevant stakeholders affiliated to the members of the consortium, but not directly involved in the design and development phases.

These demonstrations took place in the form of remote workshops, where the FACTLOG functionalities have been showed and discussed. Where possible, real historical and runtime data have been used to increase the realism of the demonstrations. Thinking aloud discussions have been strongly encouraged, since they have been considered as a pertinent method to foster the emergence of uncovered issues and / or additional features relevant to the industrial context.

Moreover, a survey has been conducted after each workshop. The details on the indicators are provided in Chapter 2.4, while the questionnaires are reported in Annex A.

Figure 5 isolates the criteria used for the evaluation in the first cycle, considering only the objects actually considered in this cycle.

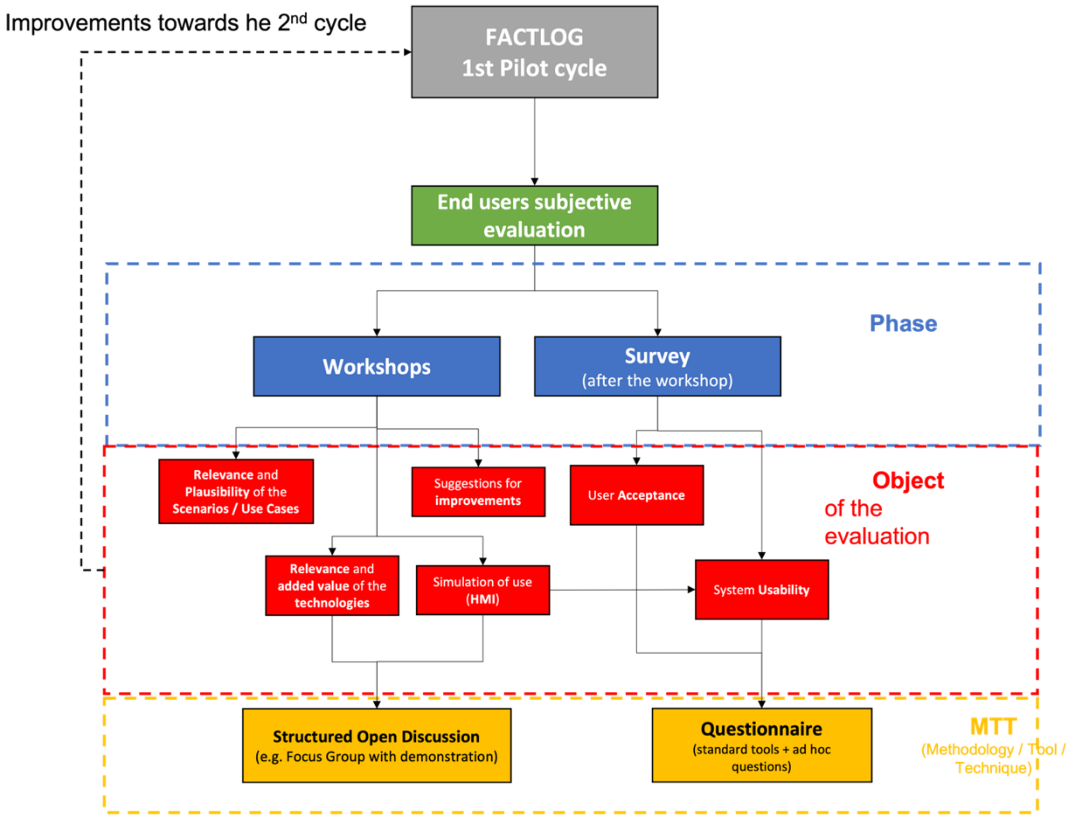

Figure 5: Implementation of evaluation framework on "end users' evaluation" for the first cycle

To summarize, the open discussions focused on the relevance and the feasibility of the selected scenarios / test cases, on the relevance of the modules implemented in each pilot and in collecting specific suggestions for improvements towards the second project cycle. On the other hand, the survey focused on Usability and User Acceptance aspects; in this phase, no subjective market-related parameters (e.g., “Willingness to Buy” and “Willingness to Pay”) have been considered, since it has been reflected that it could have been misleading to collect info on these indicators, because the platform is still at an intermediate version. These parameters will be included in the final project assessment.

Regarding the usability and acceptance parameters, the results collected in this cycle will be also considered as a baseline for the final assessment, to compare the delta between the intermediate and the ultimate implementation and to objectively measure the improvements in the second development cycle.

Concerning the third assessment category (“Impact evaluation”), the scope of the intermediate step is only to measure the validity of the KPIs previously defined. This will be a key factor for the measurement of the actual impact of the project on the industrial cases, and to tailor the exploitation strategies.

Additional details on the evaluation method and the results obtained in this cycle will be reported in D7.5 “Validation and impact assessment”.

2.4 Indicators and tools used for the evaluation

One of the activities performed in this cycle consisted in collecting from the State-of-the-Art relevant methods and techniques to measure some end-users related parameters, e.g., in terms of subjective satisfaction.

Even if great attention has been placed in the outcomes derived from the discussions performed in the workshops, some questionnaires have been provided to the relevant stakeholders to complement the qualitative results with some quantitative (even if subjective) metrics, able to provide concrete and measurable feedbacks, and to serve as a baseline for further development and evaluation steps.

To fulfil this aim, after the workshops, end-users’ participants were asked to answer a survey including some standard tools, i.e., the System Usability Scale (SUS) and the Van der Laan Acceptance questionnaire, plus some additional specific questions on the perceived usefulness of the features enabled in each pilot.

System Usability Scale (SUS)

The SUS questionnaire is quite general but brings a crucial benefit: its results can be compared also across different domains and different systems. In fact, despite their level of detail and in-depth analysis, a consequence of the context-specific usability analysis is that it is very difficult to make comparisons of usability across different systems. It is also difficult and potentially misleading to generalise design features and experience across systems. If there is an area in which it is possible to make more generalised assessments of usability, it is the area of subjective assessments of usability. Subjective measures of usability are usually obtained using questionnaires and attitude scales, which are not specific to any system [1].

To be effective and widely adopted, subjective metrics must be capable of being administered quickly and simply, but also must be reliable enough to be used to make comparisons of user performance changes from version to version of a software product. This is the case of the System Usability Scale (SUS), that is a simple, ten-item scale giving a global view of subjective assessments of usability [2].

Basically, SUS is a Likert scale [3]. Users were requested to evaluate the system they just tested as a whole. Responses were on a five-point scale from 1 (totally disagree) to 5 (totally agree). The mean of global values gathered with SUS represents the level of average satisfaction of the sample. The score calculation is the following:

- For odd items (1, 3, 5, 7, 9) the calculation is: score assigned by the participant -1
- For even items (2, 4, 6, 8, 10) the calculation is: 5 – score assigned by the participant
- The scores are added
- The obtained value is multiplied by 2,5 (the resulting score oscillates between the lowest value "0" and the highest value "100").

This type of calculation is needed to properly refer to the user judgment: since questions highlight both positive and negative issues, while the answer scale does not change, it is necessary to properly weight users' scores.

It is important to highlight that SUS is not a diagnostic method: it is used to classify the ease of use of a system, object, application, or service.

The main advantage of the SUS scale is that, giving a 0-100 score, we can compare the score collected in different situations, even if the object of the test, the context and the end-users are different.

Van der Laan Acceptance questionnaire

User acceptance is a key factor for the adoption of a technology; this criterion reflects one's attitudes towards this technology. In other words, it refers to favourable or unfavourable evaluations of a technology and its usage.

Various acceptance scales exist in the literature, mostly based on intention to use. In this study, this indicator has been measured by a standard scale developed by Van der Laan and colleagues [4]. The scale consists of nine items measuring two factors: perceived usefulness (useful/ not useful, good/ bad, effective/ superfluous, assisting/ worthless, and raising alertness/ sleep-inducing) and perceived ease of use (pleasant/ unpleasant, nice/ annoying, likeable/ irritating, and desirable/ undesirable).

Participants evaluated each item on a 5-point Likert scale ranging from -2 to 2.

Other questions on Features perceived usefulness

This section of the questionnaire was aimed at evaluating the relevance of the features designed in the first cycle, and their capability of covering the end-users' needs and meet the expectation in the context of the test cases.

For each pilot, a set of the most relevant features (i.e., functionalities enabled by the FACTLOG platform and ecosystem) was presented to the users, and it was asked to evaluate their subjective usefulness on a 5-points Likert Scale.

This evaluation allows to rank the functionalities in the actual pilot framework, to understand which one needs further work in the second cycle, and eventually correct the approach for features considered as not useful / meaningful for the specific context.

General feedbacks on system performance and features

In order to maximize the feedbacks collected from the questionnaire, room for open comments has been provided in the digital version of the survey. The scope of this section was to gather a summary of the suggestions to improve the platform in the second development cycle. For this reason, in this section, it was requested to the users to provide their impressions regarding the features to be added, the main weaknesses found and possible solutions deriving from their end-users' experience.

The results from this section will be used as qualitative hints for the new developments.

3 Waste-to-fuel Transformer Plants: JEMS pilot

3.1 Summary of the pilot

JEMS is developing and selling waste-to-fuel transformer plants. These plants are transforming any hydrocarbon-based waste into a high-quality synthetic diesel. In these plants, JEMS uses a chemical-catalytical de-polymerization process that runs on low temperature and low-pressure. Due to the low temperature, no harmful gasses (like dioxins or furans) are produced as by-products. More specifically, the process temperature of this technology is a few hundred degrees lower than the threshold to produce carcinogenic gasses. Organic waste that can be used includes wood, paper, waste fuel & oil, plastics, textile, rubber, agricultural residues, weed, cultivated plants, coal, crude oil, and others. The quality of the produced synthetic diesel fuel is one of the highest. Due to the high cetane index, flash point, low sulphur content and low clouding point, the synthetic fuel can be used in any modern diesel engine or electricity generator without any negative technical or mechanical impact. It can be used for any modern or older diesel engine for transportation and/or electricity generation as well as for heating. As a result of a chemical process, the chemical composition is stable and can therefore be also used for long-term storage. Furthermore, such diesel can be used as an additive for low temperature use due to its very low clouding point.

The latest such transformer plant is an industrial rate machine for the chemical transformation of organic waste material into high-quality synthetic fuel. The transformer plant has been designed and built for continuous operation. This plant is already using the latest available software and hardware technology allowing remote control and maintenance of each part of the plant and the process itself. However, it does not include any analytics, anomaly detection, prediction or optimization features. There is a high need for better understanding, optimization and decision making given the availability of data.

JEMS pilot did not meet its objectives, especially with regards to the integration of the FACTLOG system to its plant since there is not yet an operative plant in Slovenia.

3.2 Expected benefits of FACTLOG on the pilot

Within FACTLOG, JEMS is expecting to upgrade the existing plant with management, predictive and proactive features The approach used in this pilot is based on a novel integration of the data- and model-based approaches (analytics and deductive reasoning, respectively) enabling the so-called data-model continuum (data analytics generates models, reasoning produces implicit data) that is the basis for achieving the requested self-improvement. It belongs to the novel trend of data-enabled AI, which connects Big Data, HPC and AI, enabling the realization of the computation intensive AI methods on high performing computation architectures (including edge resources, like GPUs).

Note that such plants are typically installed in rural and remote areas, for various feedstocks and run under different conditions across the globe. Currently they are being operated with highly qualified personnel and with high cost of personnel training. Introducing automation, remote control, optimization and interconnectivity between the plants, would significantly ease the operation.

3.3 Evaluation workshop setup

Expected/executed date: 30 September 2021

Participants: main technology partners JSI, Qlector, JEMS, MAG and other interested technology and pilot partners who showed interest

Modality: web workshop; main technology partners show the interface and explain the implemented functionalities; group discusses how these functionalities meet the expectations from the proposal and how the pilot functionalities were limited for the implementation controllability purposes.

4 Oil Refineries: TUPRAS pilot

4.1 Summary of the pilot

TUPRAS is producing refined products with a complex network of process lines and the focus is on the Liquefied Petroleum Gas (LPG) production and storage section. Main scenarios important for LPG production and storage are the following (as described in deliverable 1.2):

a) Identifying a potential anomaly in a particular phase of the process
b) Understanding the impact of this anomaly in the whole context of the LPG flow in an attempt to find the optimal interventions.

The below is a full representation of the cognition process. The need for cognition comes from the fact that anomalies come from different sources:

- Off spec production
- Sub optimal production

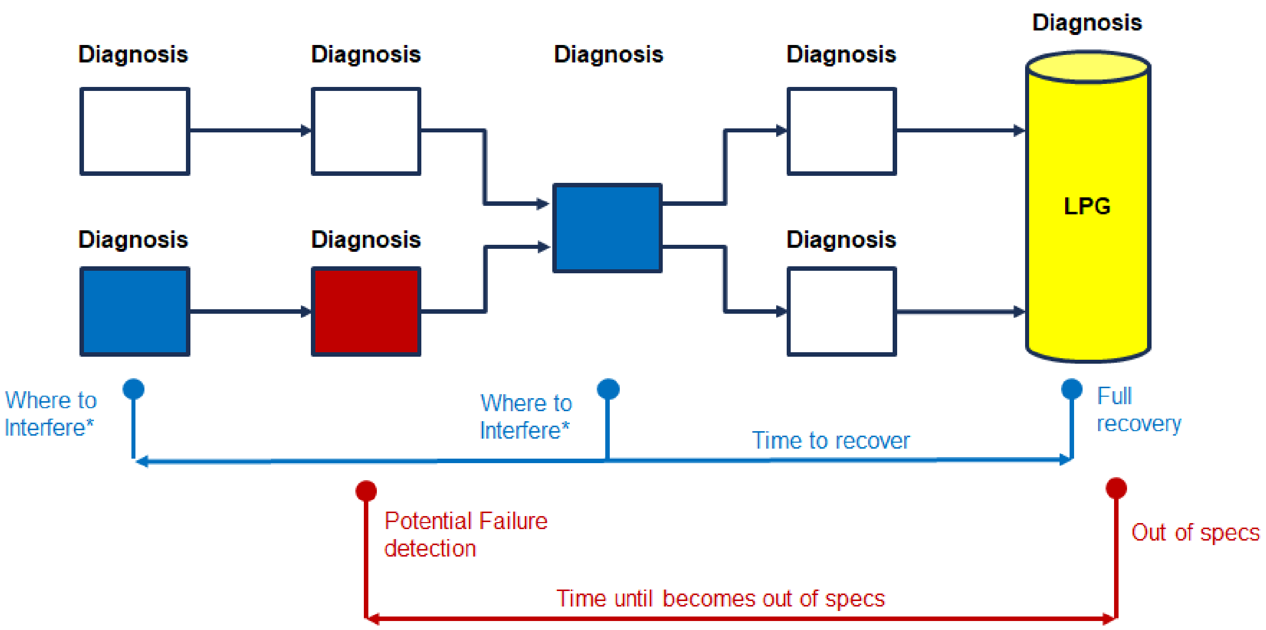

Figure 6: Anomaly detection, impact assessment and understanding intervention points (indicative schema)

Another aspect of the FACLOG project is the optimization perspective. The optimization aspect of the framework is responsible for the provision of a global optimization solution relevant to the recovery from off-specs LPG production within a given timeframe, while minimizing energy consumption.

Pilot data management

Data infrastructure was planned as shown in the figure below. The figure presents the components that are involved, both on premise and on the platform side, for the interim installation of the FACTLOG platform (more details explained in deliverable 7.1). The schematic representation of the data infrastructure was decided with participation of both technical and TUPRAS partners. The implementation was not completed but TUPRAS information technologies department was involved in the implementation process decisions.

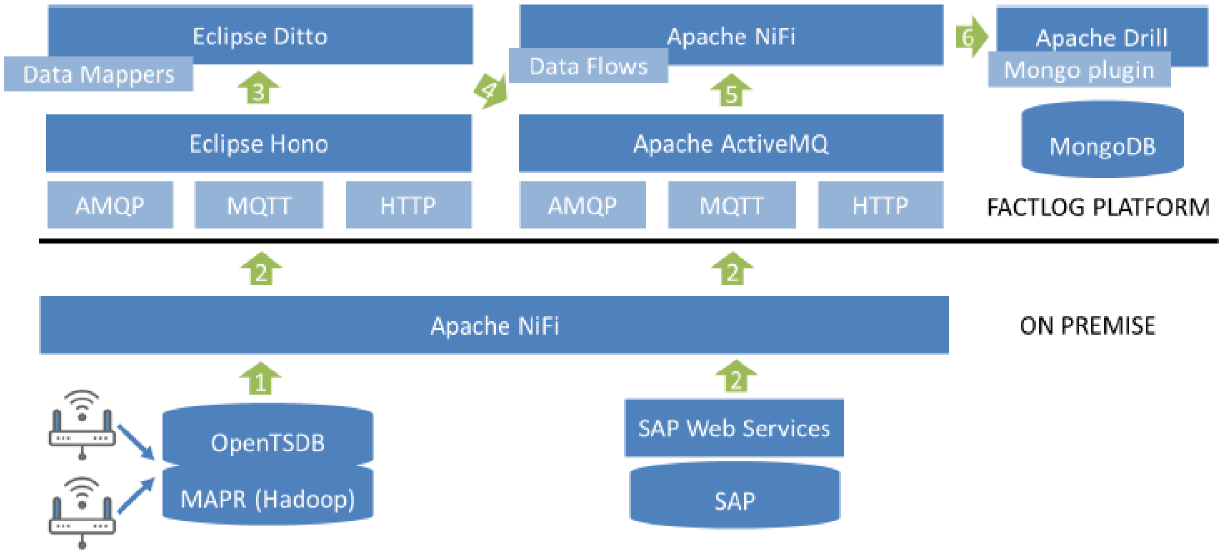

Figure 7: TUPRAS pilot data ingestion solution

The TUPRAS data infrastructure consists of an IoT device fleet capturing measurements from tanks and process units and pushing them to the TUPRAS big data platform (MAPR) which keeps historic and real-time data from both processes and product qualities. Above MAPR, the OpenTSDB database is used to push data to other platforms and services. Additionally, SAP system is used to keep track of selling and tanks' full test information. In order to connect these data sources to the FACTLOG platform, an Apache NiFi installation, managed by TUPRAS, is configured to periodically monitor the data sources and publish deltas to the platform.

About the portal

The FACTLOG platform designed for TUPRAS case mostly focuses on the prediction and monitoring of the C5 amount in the LPG for the first cycle. Both the dashboard screen and equipment screens have targeted specifically the C5 specifications. The optimization and simulations aspects were easily navigated through the portal and comprehending the usage of the optimization and simulation was very straightforward.

Digital twins were implemented to the platform, but they are not working online for the first cycle. The list of the digital twins is integrated the platform with property of viewing them separately.

4.2 Expected benefits of FACTLOG on the pilot

LPG process lines are ending up with sales process from the LPG storage tanks. The LPG sales are directly dependent on their C5, C2, vapour pressure, total impurity, and sulphur content. If any of the five specifications goes above the specified values in the table below, the LPG needs to be reprocessed or mixed with more purified LPG stream for preparing to sell the product. The root-cause analysis is very time consuming especially for the non-LPG experts. In holidays or weekend engineers on call from various expertise are monitoring the refining production. If there is an off-spec situation for LPG, the searching process for finding the abnormal equipment will begin. The searching process covers eleven debutanizers, two deethanizers, etc. and their 24-hour processes since the test for specifications are performed only just after the tank is filled. Just one test after 24 hours of production and storage makes the root cause analysis very handy. The process or production engineer need to look at all LPG related production columns and their 24 hours of production data to identify the cause of the fault. The expectation from the platform is to clearly identify the faulty process among all and propose a corrective action. The time spent for the root-cause analysis done manually will be reduced drastically by the implementation of FACTLOG platform to the TUPRAS pilot. In addition to time saved with platform implementation, decision support is the other significant offering of the platform.

4.3 Evaluation workshop setup

Pilot workshop was held on the 25th of September with participation of the pilot owner, Maggioli and the main technical partners supporting the pilot. From the Tüpraş side, end users coming from R&D and production departments, as well as some human machine interface experts attended the meeting and gave their opinions about the current version of the FACTLOG platform, expressing their needs about the further developments. Workshop agenda was shared with the attendees beforehand and a questionnaire was also shared with the relevant participants.

5 Textile Industry: PIA pilot

5.1 Summary of the pilot

FACTLOG pilot for PIACENZA case will focus on one of the most relevant and critical phases of the fabric production, the **weaving process**.

Weaving consists of interweaving the warp and weft threads to transform the yarns into high quality fabrics. This phase of the process is particularly relevant to the industrial case of PIACENZA, for several reasons. Firstly, because it represents a crucial node in the production process of the company in terms of management and monitoring of quality; secondly, because this phase is particularly critical both in terms of management of orders and priorities and in terms of energy consumption costs.

For these reasons, the weaving phase is requiring a deep effort for PIACENZA in terms of pursuit of optimization of the process and reduction of waste and inefficiencies. As already specified in D7.1, the current system running in the production plant is organized as follows:

- i) **Machine layer** that contains the production machineries (e.g., loom)
- ii) **Control layer** that collects data from machineries and manage them by a set of industrial devices (PLC)
- iii) **Data layer** that contains collected information stored into a set of databases

In FACTLOG, PIACENZA is focusing its effort on the first and the third aforementioned layers.

Regarding the Machine layer, PIACENZA has installed in the framework of FACTLOG a sensor developed by UNPARALLEL for runtime and historical consumption monitoring of the looms; at this stage of the project, one sensor has been installed and tested, and the data collected have been integrated to the datasets to enable the different services hosted by the FACTLOG platform.

This sensor is currently running in the real industrial production environment of PIACENZA. The installation of additional sensors in other looms of PIACENZA plant is already planned for the second project development cycle.

Regarding the Data layer, the pilot is focusing on extracting more information from existing machineries, in order to enrich the MES and the ERP systems with other data able to improve the accuracy of the scheduling.

Additionally, to these existing layers, additional levels called **Production organization** and **cognitive digital twin** (that represent legacy systems, MES, ERP and additional components for analysis, inference, and optimization) and **Representation layer** (i.e., the visualization system to display to different types of users – e.g., “admin” and “operator” - information on the production environment, and provide to rights to update the planning) will be included in the real production process thanks to FACTLOG.

At this stage of the project, the PIACENZA pilot will evaluate an intermediate version of both the Test Cases defined in D7.2:

PIA-TC01: Access to New Data Streams

This scenario tests how changes in PIA data sources are accessed by the FACTLOG platform in a meaningful way in order to create knowledge about the performance of the modelled assets / processes.

Regarding this test case, the scope of this stage is to verify that all the expected process modelling features are covered by the FACTLOG platform, in order to consider them as a starting point for the refinements planned for the second stage. Moreover, the other aspect analysed is related to the level of comprehension of the evidence displayed to the user, as well as the affordability of the information.

PIA-TC02: New production plan formulation

This scenario tests the on-demand generation of a new production plan. The scenario begins with the system detecting changes to the current production state that disrupt the production plan e.g., a loom breakdown or a new order, and allowing the user to request an on-demand production plan optimization.

Regarding this second test case, the focus is placed on a specific aspect of the production management system. The scope of the workshop is to verify the understandability of the changes in the production plan and the perceived easiness of the re-planning.

5.2 Expected benefits of FACTLOG on the pilot

As already introduced in previous deliverables, two different (and theoretically conflicting) objectives are considered in this pilot: to **maximize production performance**, represented by the average warp length, and to **minimize order deadline delays**. These objectives can be considered conflicting since, usually, the rise of new urgent orders lead to a loss of performance in terms of efficiency of the looms.

The implementation of the former objective is aimed at minimizing the usage of energy (electrical power and gas), reduces the machineries queue time and speeds-up the production but could increase order delays. The latter objective minimizes the economic cost related to order delays but could increase energy consumption and machineries queue time.

As defined in Chapter 2, this cycle of the pilot evaluation is not focusing on the technical aspects and KPIs, but rather on evaluating the impact of the features implemented and the factors related to the interaction of the users with the platform in the defined scenarios.

So far, the main applications involved in the evaluation of the PIACENZA case are the optimization of the production schedule and data analytics module, to match respectively the aforementioned objectives.

In the second cycle, additional features will be evaluated with the involvement of external end users (e.g., coming from other industrial companies). In particular, the evaluation will also focus on the economic impact of the FACTLOG solution as well as on the intention of adoption shown by the potential users.

Moreover, the technical evaluation in the real industrial context will be performed, in order to assess the impact on the plant performance and to measure the industrial fallout of the innovations developed within the project.

5.3 Evaluation workshop setup

The workshop has been hosted the 28th of September 2021. In order to comply with the COVID-19 restrictions still active in Italy, the workshop was completely handled remotely.

The partners actively involved in the pilot (i.e., the modules developers, the platform developers and technical support of the pilot, in charge of handling the data extraction and the data ingestion processes) have participated to the workshop.

Additionally, a sample of people from the end-user (not directly involved in the project) has participated to provide feedbacks on the current development, and to drive the design of the platform and the applications in the second project cycle. 4 persons of PIACENZA, strongly aware of the production processes and, in some cases, not directly involved in FACTLOG, participated to the workshop.

The same sample has also provided answers to the questionnaire, in order to allow the evaluation of Usability and Acceptability parameters, as defined in Chapter 2.

The workshop started with a short introduction of FACTLOG project, intended to clarify the project scope and concept to people not directly involved. An introduction on the test cases has been also provided to define the scope of the project.

Then, a demonstration of all the different functionalities enabled by the platform has been done, in order to show the potential of the integrated system. The demonstration has been performed using real plant's data, coming from looms in real production set up, used to train the modules and to perform the simulations. Participants were asked to provide observations, e.g., on the data visualization modalities (e.g., representations of production GANTT chart, a unique view of all the looms in the weaving department etc.) and on the prominence of the information displayed (e.g., what an ideal user would see on a principal dashboard page, which are the main data to be shown regarding the single looms digital twins).

Additionally, it has been performed a standalone demonstration of the Analytics module, used to monitor energy consumption data from the sensors installed in the weaving department in the first project cycle. The module is currently developed but not integrated yet in the platform for PIA case: one of the scopes of the second cycle (besides extending the covering of sensors to other looms) will be to integrate it in order to enrich the digital twins and to provide the end users with more information, also coming from pseudo real time data.

The outcomes of the workshop, including the comments and insights provided by the relevant stakeholders, and the results of the survey will be reported in D7.5.

6 Automotive Manufacturing: CONT pilot

6.1 Summary of the pilot

In the context of the FACTLOG project, Continental focuses on the Final Assembly area. Every machine on the Final Assembly line is equipped with sensors and their measurements are sent to traceability system via the network. For each process, Continental stores specific data into traceability database. This data is the basis for the project and represents the RAW data for the applications provided by the project. Through FACTLOG project, Continental Pilot is pursuing the improvement of monitoring the Pre - Assembly lines and the Final Assembly lines and moving from only one parameter monitoring to automatic reporting, automatic preventive maintenance in order to reduce/limit the number of down times caused by breakdown.

Processes are implemented with state-of-the-art technology components (e.g., screwdriver controller, axes systems for positioning, PLC for controlling the station).
On each equipment an HMI (Human Machine Interface) exists which the operator interacts with. In this way, the operator knows the status of the machine and the step sequence of the process. Specific communication with the MES system for traceability and process control is already implemented in Continental pilot line. By this, Continental has the entire setup for its production and data storage.

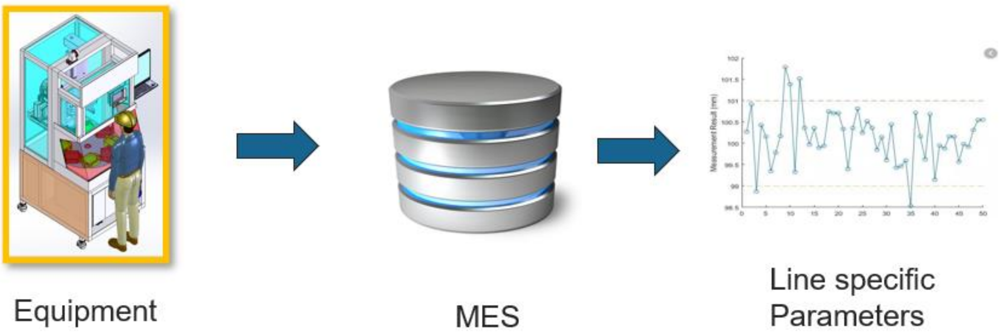

Figure 8: Example for screwing process

Continental pilot needs to have a focus on finding the right balance in terms of cost vs number of failures in the Final Assembly Line to reduce the maintenance cost:

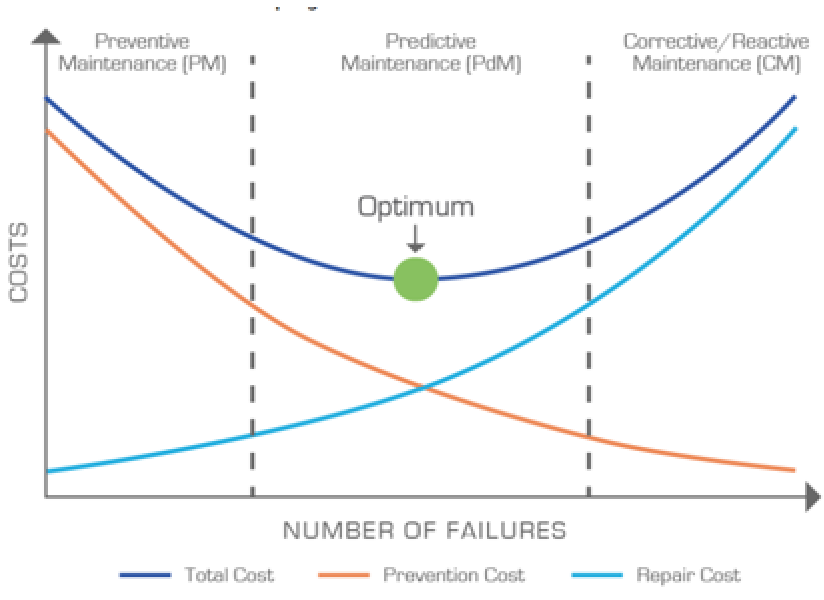

Figure 9: Expected cost reduction in FACTLOG for CONT case

The reduction of equipment energy consumption by interacting with the production planning is an important need for Continental that the outcome of the FACTLOG project should take care of.

Some of the challenges that the Continental pilot faces can be summarised as follows:

- Fast product changes, more different product families on the same assembly line
- Increasing product complexity at lower costs
- Product needs perfect quality (ornamental element)
- Increased amount of electronics used in Final assembly lines
- No correlation between the line ON/OFF state and production scheduling
- Different timing in industrialization of a product (low ramping up volume vs digital ramping up volumes)
- Different approaches of warranty and service contracts with suppliers.

6.2 Expected benefits of FACTLOG on the pilot

Continental Pilot's expectations from the FACTLOG project are described below:

- Reduction of down time caused by breakdown due to possibility to forecast issues and plan them in preventive maintenance.
- Improve the Overall Equipment Efficiency (OEE) by increasing the availability and increased quality of the Final Assembly Line.
- Automatic identification of the Optimum cost for maintenance.
- Monitoring of maintenance cost % of total operational cost / equipment.
- Automatic identification of the Final Assembly Line status (plan/no plan) and Final Assembly Line energy consumption module.

- Automatic safe mode “shut down” and “wake up” based on production scheduling.

The main issues for Continental are:
1. Self-diagnosis and predictive maintenance at each machine
2. Aligning Predictive Maintenance with production plan
3. Optimized operational mode per machine
4. Energy and performance monitoring using dashboards.

In the FACTLOG process, these issues are going to be approached using DT modelling and cognition as described in deliverable “D1.1 Reference Scenarios, KPIs and Datasets”.

By solving these issues, the objective is to improve the values of the KPI as presented in the following table:

Table 1: Reference KPIs for CONT case

KPI	Today	With FACTLOG
Machine downtime because of breakdowns	>8%	< 5%
Total maintenance costs as a percentage of total operational costs	18%	<12%
Energy consumption of idling machines as a percentage of total energy	>11%	<7%
Overall Equipment Efficiency (OEE)	80%	>87%

6.3 Evaluation workshop setup

At the time of writing this deliverable, the workshop is set to be done on 12th of October 2021 and will be organised as a virtual meeting. The workshop intends to start with a retrospective of the Continental pilot’s needs, but also of its expectations regarding the results of the FACTLOG project and to continue with a presentation of the platform developed by Maggioli (intermediate version) with the Digital Twin Representation. During the workshop, feedback will be collected from the end-user to confirm if the features already developed are relevant and to acknowledge what could be improved for the final version of the platform.

The list of workshop participants from the Continental pilot includes the following responsible people within the organization:

- Mr. Flavius Mihaila – Head of Industrial Engineering
- Mr. Alin Popa - Group Leader Smart Factory Industry 4.0 group
- Mr. Cristian Bozan – Leader of the Automation and Mechanical Engineering team
- Mr. Lucian Pavel – Leader of the MES team
- Mr. Bogdan Posa – Automation engineer
- Mr. Ciprian Kamenik – MES Engineer
- Mr. Bogdan Helgiu – Production planner

SIMAVI, as the technical partner supporting the Continental pilot, will be represented by the Project Manager in the FACTLOG Project on behalf of the organization, Mrs. Andreea Paunescu, and the technical leader in FACTLOG Project, Mr Radu Popescu.

MAG’s technical team and the representatives of the technological partners who developed the modules for the Continental pilot will also participate in the workshop.

7 Steel Manufacturing: BRC pilot

7.1 Summary of the pilot

As set out in deliverable D1.2, the objective of FACTLOG is to improve current optimisation capability and increase production. This will be done through managing the following aspects:

- Orders will be prioritized on receipt depending on delivery requirements, raw material, and machine availability
- To optimize the production flow and loading schedules to trailers
- Schedule maintenance based on a stochastic model of machine performance to predict failures so they can be dynamically integrated into production schedules.

This will be done by using a holistic approach to the factory with digital twins to take in the relevant datasets that are required to have a live view of the situation and allow a more optimal workflow of product through the factory floor. The digital twins proposed to be integrated into the solution was machine and crane digital twins.

The machine digital twin will take into account the following sets of data looking for variations:

- Step time - variations in time per unit distance (require shape code info)
- Mains Current – variations in current demand / feed speed in operation and at rest
- Mains power – variations in power demand
- Hydraulic temperature – variation in temperature outside operating parameters
- Hydraulic pressure – variations in pressure at rest and operating
- Step power – power required to perform feed, bending and cutting operations (require shape code info)
- Step time – time taken to perform feed, bending and cutting operations
- Feed speed command – feed command value for bar to be used with step power/time
- Variables
    - Bend angle command – command for bend operation to be used with step power
    - Time variable

The crane Digital Twin's should take into account:

- Pick-up times
- Travel times
- Drop times

With these datasets taking into account information from the digital twins and existing datasets, FACTLOG creates a more optimal optimisation scenario and variation detection system to allow for increased productivity overall.

Currently the architecture that has been instantiated in the project up until now has been based on the gathering of data for key datasets from historical data, in order to allow for analysis of requirements in regards to implementation of the optimisation system. In regards to digital twins, a telemetry box will be set-up to take the live datasets in order to provide the data for live optimisation, and a crane telemetry system has been designed to take the lag times between crane movements for further accuracy in optimisation.

In regards to the pilot's focus, it is currently establishing data systems to handle the data generated by the installed digital systems on BRC's systems and then the transferring of the data to the FACTLOG architecture. Without this, currently BRC is using historical data and modelled data to perform the first iteration workshop.

To exploit above set out architecture and benefits, several scenarios are identified to be achieved in order to realise the results. These scenarios are shown below:

- Scenario #1: New Data Streams and Storing
- Scenario #2: Anomaly detection
- Scenario #3: Production Scheduling taking under consideration availability of machines
- Scenario #4: Production Scheduling taking under consideration availability of machines and crane movement

In Scenario 1, currently the new data stream architecture and methods of capture have been established for most of the data required; in this direction, a hardwired database shall be installed in Newport in order to collect and collate the data. This will be fed into FACTLOG via the digital twins that will be mentioned later in the following scenario. For scenario 2 there are currently activities in place for anomaly detection on machinery with a prototype datalogger unit being applied to an Automatic Link Bending (ALB) production unit, which will allow readings to be taken from the machine creating datasets. These datasets can then be used for anomaly detection, for calculation and AI to predict if there is an issue developing in regards to the machine.

With scenario 3 there is a plan to use both the datalogger and manual entry of machine availability to then make decisions on the best production workflow of product through the factory floor. This is in conjunction with analysis of the production timings given by the datalogger unit, machines equipped with industry 4.0 technology and existing MES system through scan times. The final scenario 4 is then using the crane lag times taken by a crane DT system in order to calculate pick-up, movement and drop down times, which become an overall lag time for the cranes, further assisting in optimising the workflow of production.

In the current state of the pilot, the key data architecture has been designed and is currently under development, with a server being set-up ready to gather and collate the DT's datasets as well as the existing ones to be passed to FACTLOG. The machine datalogger to be set up on an ALB production unit had faced delays in that the existing machine that had been planned to be fitted to has been replaced with newer machinery, hence a more viable machine has been identified. The benefit however is that the new machinery has industry 4.0 capability on it, meaning that datasets can now be accessed from these machines which BRC hopes to utilise for the purposes of the project. In regards to the crane DT, the design has been established but is in the process of being put into action with the hope to have a fully functioning monitoring system on one crane.

In regards to optimisation, modelling and analytics development, for the purposes of the workshop historical datasets have been put forward for the use of simulation and a set of parameters have been given to analytics for the purposes of simulation, until the datalogger unit and key live DT data is available to the group. In the workshop, the optimisation programme should be available for demonstration of key features.

7.2 Expected benefits of FACTLOG on the pilot

The added value by FACTLOG in context of the end user is vast and explained in the bullet points below:

- Increase visibility of the Factory floor and machinery performance
- Increased Industry 4.0 capability advancing the business
- More Automated optimisation based on real-time data
- More holistic optimisation scenarios due to a more inclusive factory view
- Predictive maintenance with AI prediction for fault detection
- Increased machine performance analysis
- Analysis of crane performance
- Can prioritise via makespan or delivery schedule, meaning more optimisation options for different scenarios

7.3 Evaluation workshop setup

The workshop setup for end-user evaluation of iteration 1 is as follows:

- Date set for the workshop is Thursday 30/09/2021.
- Mode of demonstration is via Microsoft Teams due to conferencing capability and taking into account Covid-19.
- It is presented by Control2k, the lead technical party for the BRC Pilot.
- The workshop shall last an hour.
- Questionnaires are filled in after the workshop.
- Participants from BRC end users: Operations manager, Engineering manager, Senior production manager, Planning and Transport manager, Industrial Process Engineer/Quality Analyst.

Conclusions and next steps

This document has reported the preliminary implementation of the pilots, as well as the common methodological framework created to evaluate FACTLOG system in the real industrial contexts defined in the pilots.

Moreover, it also defined the strategy to split the actual evaluation between the first and the second cycle, focusing the first one on User Interface and features related evaluations, and the second one on more technical and impact-related topics.

Regarding the implementation status, an intermediate version of FACTLOG platform demonstration has been developed and shown for all the pilots' contexts. At this stage, most of the functionalities have been developed up to an intermediate version, and meaningful comments and suggestions for improvements in the 2nd cycle have been collected during the workshops.

In D7.5, the results of these workshops will be detailed, also providing some structured actions for enhancements in all the pilots, both referring to usability and functionality aspects. Additionally, first results on User Acceptance will be provided, also to be used as a baseline for the second cycle. Moreover, first qualitative insights on the KPIs will be introduced, in order to verify their relevance.

The update of this report (D7.4, expected for M40) will use this as a basis to provide refinements of methodologies and actual implementations, and to highlight the gap between the first and the second cycle in terms of technical implementation and status of the integrations.

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[4] Van Der Laan, Jinke D., Adriaan Heino, and Dick De Waard. "A simple procedure for the assessment of acceptance of advanced transport telematics." *Transportation Research Part C: Emerging Technologies* 5.1 (1997): 1-10.

[5] usability.gov/how-to-and-tools/methods/system-usability-scale.html

[6] hfes-europe.org/accept/accept.htm

Appendix A – Questionnaire used for the 1st cycle of pilots evaluation

System Usability (System Usability Scale)

ID	Question	Strongly Disagree				Strongly Agree
		1	2	3	4	5
1	I think that I would like to use this system frequently.					
2	I found the system unnecessarily complex.					
3	I thought the system was easy to use.					
4	I think that I would need the support of a technical person to be able to use this system.					
5	I found the various functions in this system were well integrated.					
6	I thought there was too much inconsistency in this system.					
7	I would imagine that most people would learn to use this system very quickly.					
8	I found the system very cumbersome to use.					
9	I felt very confident using the system.					
10	I needed to learn a lot of things before I could get going with this system.					
How to score		[5] https://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html				

Perceived usefulness of the Features*

Rate how much the features would be useful for your work						
ID	**System Application**	**Not at all**				**Significantly**
		1	**2**	**3**	**4**	**5**
1	Feature 1					
2	Feature 2					
3	Feature 3					
4	Feature 4					
5	Feature 5					
How to score		5-points Likert Scale (1=-2; 2=-1; 3=0; 4=+1; 5=+2)				

*The actual features presented to the users differ among all the pilots, to reflect the actual features covered by the FACTLOG applications in each specific test scenario.

User acceptance of the FACTLOG system (Van der Laan questionnaire)

I found the system:						
Useful						Useless
Pleasant						Unpleasant
Bad						Good
Nice						Annoying
Effective						Superfluous
Irritating						Likeable
Assisting						Worthless
Undesirable						Desirable
Raising Alertness						Sleep inducing
How to score			5-points Likert Scale (1=-2; 2=-1; 3=0; 4=+1; 5=+2) Acceptability Threshold = 0 [6] https://www.hfes-europe.org/accept/accept.htm			