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FACTLOG
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ENERGY-AWARE FACTORY ANALYTICS FOR PROCESS INDUSTRY

Deliverable D1.1

Reference Scenarios, KPIs and Datasets

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X	**PU**	Public
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Executive Summary

Every factory has different operational contexts and needs. In FACTLOG, we are proposing a generic technology pipeline to model all assets as digital twins and offer some cognition capabilities (ability to understand, reason and act through optimization). This offering should be open, configurable per case and supported both by models and services that can be deployed and fit into the different industry needs.

This deliverable is trying to bridge our project vision and approach with the real needs of the industry. The overall approach used was to work into two inter-related ways: first, to identify “what the offer is”, i.e. to create an operational model of FACTLOG and explaining how it works and mention indicative problems and challenges that we can address. Second, to talk to the users (industry) to understand their real challenges and needs.

In D1.1, we present the results of those two approaches and describe the overall FACTLOG operational model where all its enablers are placed in an integrated way (cognition, analytics, optimization, etc.). Also, we detail the user needs and how FACTLOG operational model contributes to them.

The operational model has a generic flow pattern: it starts with the concept of modelling any asset/system/process in the industry as a network of inter-related **Digital Twins** (DTs). Those DTs interact with the physical assets in a bilateral way: collecting data and sending data. At the operational phase, we have collection of data streams from different information sources using a **messaging service**. Using a **Reasoning engine** (combining both data-driven and model-driven approaches), we can identify patterns of behaviour and potential shortfalls. **Simulation and forecasting** can propagate the behaviour of the system into the near future and assess the impact of the identified anomaly. Last, using robust optimization methods, we can improve decision-making (planning, scheduling, auto-configuration, etc.).

FACTLOG has **five** interesting and different **industrial cases**. Most of them correspond to the need of predictive maintenance, anomaly detection and mitigation, energy monitoring, scheduling and optimal machine operation status. We have identified the needs and reference scenarios (information flow and actors in line with the FACTLOG operational model) that will help in the definition of the system specifications, boundaries and pilot particularities for deployments. As a next step, we will conduct workshops with external industrial players to confirm the operational model and also identify other scenarios, which will give us a more comprehensive picture of the market perspectives of our solution. This was planned to be done in the period of the pilot analysis but due to the COVID-19 outbreak we faced problems in organizing such workshops. We expect to do this in the next months and an updated version of the deliverable to be submitted with such findings.

Through a holistic requirements elicitation approach, we expect such reference scenarios to be further detailed in the next step, which is the definition of the use cases and functional/non-functional requirements

Revision History

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0.1	11/06/2020	Structure of the document	TUPRAS
0.2	03/07/2020	Contributions to Section 1 and 2	MAG
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Acronyms and Abbreviations

CDU	Crude Distillation Unit
DCS	Distributed Control System
DT	Digital Twin
ERP	Enterprise Resource Planning
EU	European Union
FA	Final Assembly
HMI	Human Machine Interface
KPI	Key performance Indicator
LPG	Liquid Petroleum Gas
LSRN	Light Straight Run Naphtha
OEE	Overall Energy Efficiency
OEM	Original Equipment Manufacturer
PCBA	Printed Circuit Board Area
PLC	Programmable Logic Controller
PUC	Production Unit Controller
MES	Manufacturing Execution System
MPC	Model Predictive Controllers
SMT	Surface Mount Technology
WP	Work Package

1 Introduction

1.1 Scope of the document

This deliverable summarizes the findings of the initial business analysis of the pilots and external stakeholders with regards potential scenarios and cases for cognitive factories and digital twins.

The main goal is to adapt FACTLOG technology into real cases and therefore to be user-centric: aligning our technology vision with the real needs of the market, ensuring high degree of marketability and potentials for new customers.

To this end, from the beginning of the project the consortium worked to bridge two different approaches:

- The "technology-push": approach, where we defined a future Cognitive Factory operational scenario in which, all innovative aspects (Cognitive Digital Twins, optimization, analytics, cognition) work together to improve operational performance.
- The "market-pull" approach, where we tried to understand the needs of the industry and align them with FACTLOG's operational approach.

To achieve this, the consortium from the first day of the project (Kick off meeting) agreed on an integrated requirements elicitation approach which is described in the following section.

After the kick off meeting, the consortium worked on creating the operational scenario (section 2) which was also discussed in the context of each pilot case in order to assist them in defining their business cases/scenarios. The latter is presented in section 3.

1.2 Deviations faced during the business cases definition

The work related to this deliverable followed the predefined schedule at least for the pilot cases analysis. However, due to the COVID-19 lockdown the consortium faced problems in organizing external stakeholders' workshops, where we intended to enlarge the scope of the project and have an initial validation of our approach from other potential customers. By the time the deliverable was submitted (July 2020), the factories of potential external stakeholders were still struggling to handle the turmoil that was brought about by the lockdowns and hence offered no availability.

We expect that in autumn, we will organize workshops with external stakeholders and obtain additional cases and feedback. The findings of the workshops will be recorded in an updated version of D1.1 by the end of October 2020.

1.3 Methodology

WP1 will study all the operational and business aspects for cognitive factories. This represents the starting point for understanding whether new technological solutions may bring benefits in specific contexts and eventually on the whole logistics chain. For doing so, a deep understanding of the corresponding business contexts is required. In particular, the purpose is to define:

- which are the main challenges/problems the pilots are facing;
- which are the main promising areas for cognitive factories value proposition; and
- which are the main expectations from FACTLOG, from the users' point of view.

Figure 1.1 depicts the methodological approach of FACTLOG, focusing on the role of WP1 within the project ("Understand" phase).

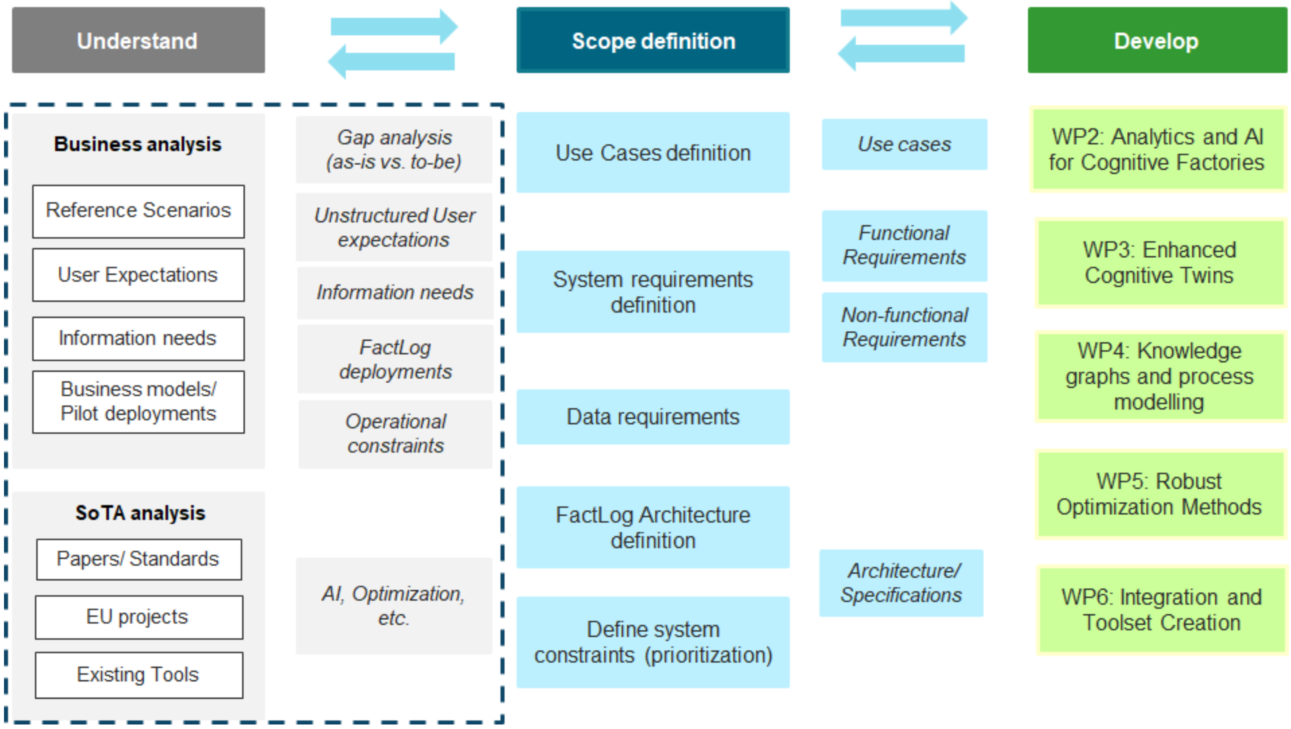


Figure 1.1 FACTLOG – Requirements Elicitation Approach

More specifically, the main activity carried out in this phase is the business analysis. The business analysis will provide the scope of FACTLOG applications from the users/stakeholders' point of view and includes the following phases:

- definition of the reference scenario with respect to the environment where pilots take place;
- gap analysis between AS-IS scenario and the needs that will be implemented through the TO-BE scenario;
- description of the information to be processed. This will help in identifying the data needed for the cognitive services and start working on the models and pilot activities (data collection);
- initial analysis of FACTLOG operational scenario – how it works and how the different project modules/offerings are working together in an integrated way.
- Initial analysis and potential deployments of FACTLOG operational model into the pilot users. Based on the user stories/ scenarios, how FACTLOG can be deployed to achieve the user expectations?

The result of the above will provide the scope of FACTLOG from the users/stakeholders' point of view.

In parallel to the business understanding, the consortium started looking at the progress on the main pillars of FACTLOG project, setting up the state-of-the-art analysis: cognitive factories, Digital Twins, semantics, Optimization services and integration of digital/physical assets. For those, the main sources are: relevant projects, industry standards and market initiatives/solutions.

Furthermore, WP1 will lay down the basis for the “Scope definition” phase; this phase will elaborate on the business analysis and define structured requirements for FACTLOG project, focusing on the technical specifications for WP2-WP6 in terms of:

- use cases/functional and non-functional requirements;
- information models, ontologies and Knowledge Graphs;
- FACTLOG cognitive framework model, architecture and components definition.

Furthermore, the technological partners will define the main system constraints that may arise from:

- operational and other constraints (as defined in the “Understand” phase);
- constraints in the functions to be developed due to resources constraints.

The results of “Scope definition” phase will be used in the “Develop” phase, as described in WP2-WP6.

It is worth noting that a key factor for the success of the requirements definition is the close cooperation of all involved stakeholders: technology providers, pilot users and others. Hence, for each pilot, the consortium has assigned one or more technology providers and research partners whose role is to facilitate pilot users in defining the business cases, unstructured requirements and also to be responsible for translating them into structured use cases and functional/non-functional requirements.

Apart from the above, the project will utilize also the networks of all consortium partners. The main goal is to validate the concepts of FACTLOG, to define more business cases and to initiate a community that will be used for both communication and, later validation activities. This is also part of the communication and marketing activities.

2 FACTLOG Operational Scenario

2.1 Overall

The cornerstone of FACTLOG operation is the **Digital Twin (DT)**. The concept of **Digital Twin** was first introduced by M. Grieves[1]. We can simply state that a DT is a digital replica of a living or non-living physical entity[2] with various capabilities in manufacturing industry[3]:

- A DT is a virtual model of a real entity.
- A DT simulates both the physical state and behaviour of the entity.
- A DT is unique, associated with a single, specific instance of the entity.
- A DT is connected to the thing, updating itself in response to known changes to the entity's state condition or context.
- A DT provides value through visualization, analysis, prediction, or optimization.
- There are plenty of DT definitions, each one focusing on different areas. According to a research study[3], there are different levels of information integration between the DT and the physical object as follows:
- A *Digital Model* is just a visualization of the object and without any data flow from and to the object. In a *Digital Model,* we can simply run simulations without information exchange with the physical object.
- A *Digital Shadow* is a *Digital Model* but with some information flow from the object to the model. In such case, a change in the status of the physical object updates the status of the digital model.
- A *Digital Twin* has a bilateral integration with the physical object by both getting information from the object and controlling the physical object.

The usage of DTs in connected factories is very important. Through DTs, a manufacturing company can virtualize its assets and have a better monitoring of their performance both at factory and intra-factory level. They can also improve Production Planning and Predictive Maintenance[4], monitor virtual production lines by connecting all involved stakeholders[5] and optimize Packaging, Materials and Logistics[6].

FACTLOG intends to integrate the concept of Digital Twin with cognitive and communication capabilities. In FACTLOG, we consider a production entity (workstation, production line,

[1] Grieves, Michael. Digital twin: Manufacturing excellence through virtual factory replication. 2014
[2] Digital Twins: The Convergence of Multimedia Technologies. El Saddik, Abdulmotaleb. 2, 2018, IEEE MultiMedia, Vol. 25.
[3] Digital Twins in manufacturing: a categorical literature review and classification, I available at:. Kritzinger, Werner, et al. 11, 2018, FAC Papers Online, Vol. 51, pp. 1016-1022.
[4] Digital Twin and Big Data Towards Smart Manufacturing and Industry 4.0: 360 Degree Comparison. Qi, Qinglin , et al. 2018, Procedia CIRP, Vol. 72, pp. 237-242
[5] DIGICOR. DIGICOR H2020 Project: Decentralized Agile Coordination across supply chains. 2019.
[6] Heutger, Mathias and Kuechelhaus, Markus . Digital twins in Logistics: a DHL perspective on the impact of digital twins in the logistics industry. s.l. DHL, 2019.

Factory) as a network of inter-connected Digital Twins, each one having different capabilities.

To realize the above concept, we need to consider an approach, where each factory entity can be modelled accordingly with different levels of cognition, communication and monitoring needs. Such configurability can be achieved if we can allow the end user to configure and monitor the physical assets as Digital Twins and associate them with the following enablers (*Figure 2.1.1*):

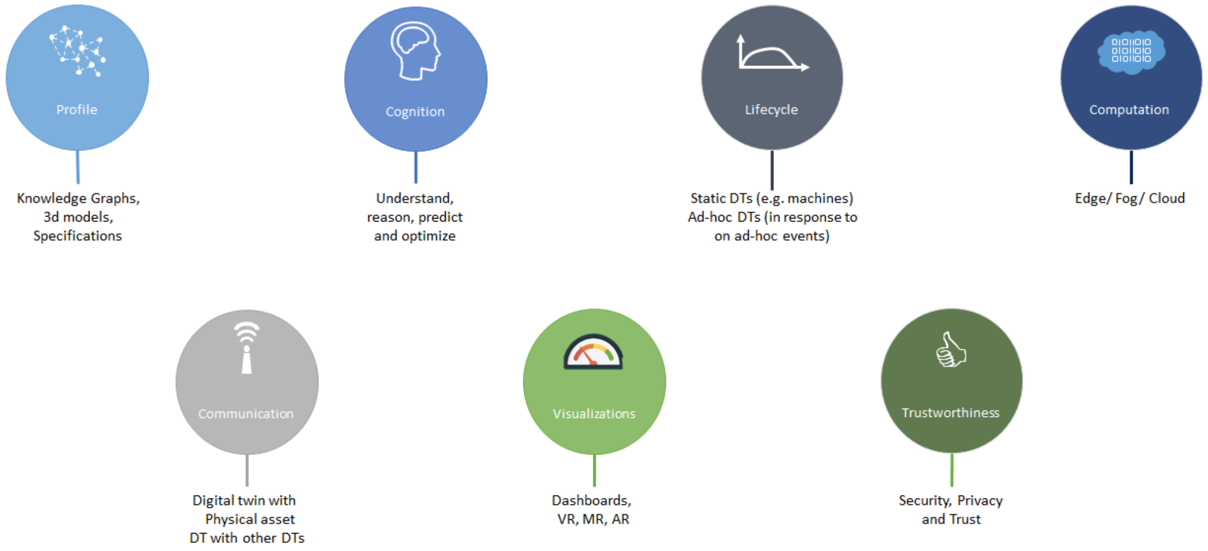


Figure 2.1 Basic Enablers of Cognitive Twins

a) **Profiling**: It provides the necessary knowledge about the physical asset's status, behavior, specifications and any other information that characterizes the asset.
b) **Cognition**: It is the ability to understand context, reason on top of existing information, predict behavior and optimize behavior. This refers to all analytics and cognition services and each Digital Twin can have different cognition capabilities (from basic sensing and understanding up to complex detection and optimization). The basic blocks of Cognition are the following:
   a. ***Reasoning services,*** which are responsible to understand a context and generate knowledge based on data streams
   b. ***Simulation and Prediction Services,*** which propagates the behavior of a DT in the future to understand whether an anomaly is about to happen.
   c. ***Optimization services.***
c) **Lifecycle**: It refers to whether a DT can be static or ad-hoc. A Static DT can be a production machine, whereas an ad-hoc can be an asset that has not long duration and is used for a specific purpose (for e.g. a 3D printer of a collaborative producer for a specific manufacturing project). A DT should be able to monitor its duration and lifetime (creation until the end of life).
d) **Computation**: It refers to the ability to perform computations (considering the load of functions and calculations need to perform. This is linked with the ability to run some services either or cloud and/or edge.
e) **Communication**: It is the ability of a DT to communicate with its physical asset and with other DTs as part of the network it belongs (e.g. Workstation A with Workstation

B, which belong to the same production line). Communication services are supported through a ***message bus*** responsible for the interoperation and information exchange.

f) **Visualization:** It refers to the ability to monitor the performance and lifecycle of a DT (using dashboards, VR, MR and XR technologies).

g) **Trustworthiness:** It refers to the security/ privacy and trust services/policies applicable to the operation of a DT and its ability to exchange information with other DTs.

The above enablers are functioning together in an integrated concept where for each of the DTs we can monitoring the flow of information from collection to understanding and behavioural alerting as indicated in the figure below:

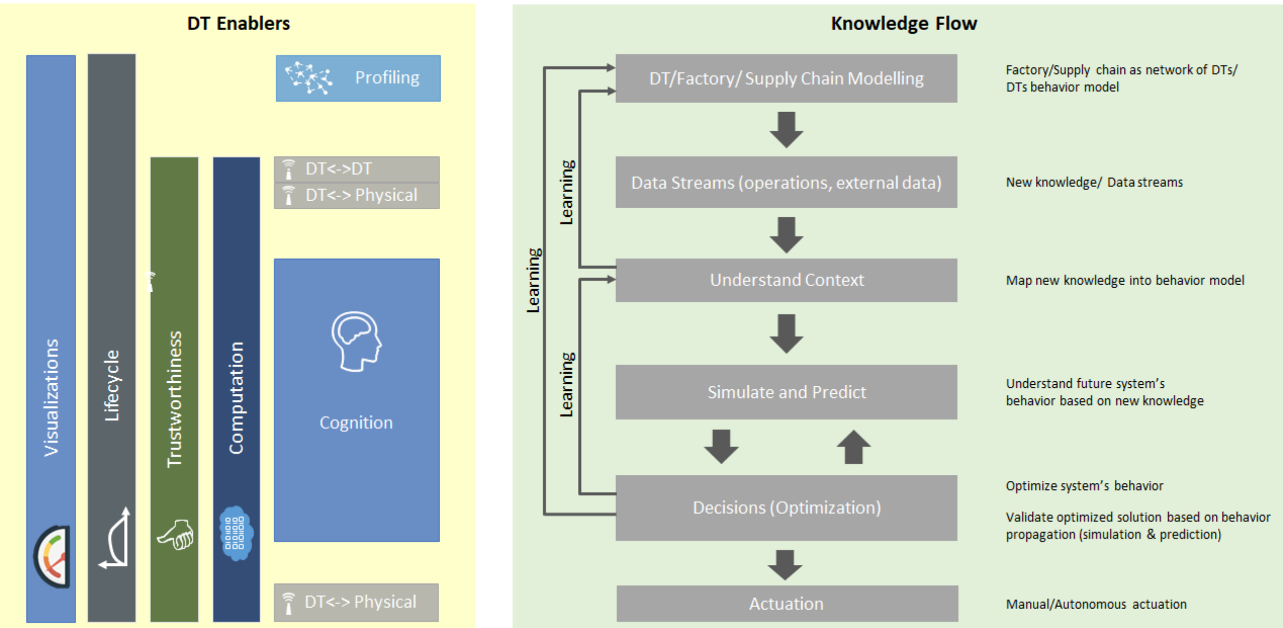


Figure 2.2 FACTLOG Operational Scenario

In FACTLOG operational scenario the main steps are:

Step #1: Modelling: this is the configuration phase, where we can model a factory or any hierarchical structure of a factory/ supply chain as a network of interconnected DTs.

Applicable Enablers:

- **Profiling**: Define the knowledge about the DT, assign relationships with other DTs (parent-child) to create the structure of the network
- **Visualization**: Monitor the configuration phase and the different parameters/DT characteristics
- **Lifecycle**: Define status of the DT, make ad-hoc or static DTs, etc.

Step #2: Collect data streams about the behaviour of the DT: Each DT will collect information about its behaviour from sensors, systems, other DTs or external sources (standards, databases, etc.).

Applicable Enablers:

- **Communication**: Communication capabilities of the DT that defines the sources of the data streams (either from the physical assets and/or from other DTs that represent different information sources).
- **Computation**: Calculations and transformations that happen either at the cloud and/or at edge.
- **Trustworthiness**: Applicable security/privacy/trust services and policies that apply in the process of collecting info from other physical asset/DTs.
- **Visualization**: Data streams visualization
- **Lifecycle**: Monitor status of the DT.

Step #3: Understand Context: Once data is collected, is mapped against the DT's behavioral model. Through cognition services, the DT will be able to understand potential trends, anomalies or create new knowledge (in the form of new rules, associations, etc.) that is not yet known.

Applicable Enablers:

- **Cognition:** Analytics based on existing behavior models or data-driven knowledge extraction that updates the existing model.
- **Computation**: refers to whether cognition services will run at the cloud and/or edge.
- **Trustworthiness**: refers to the applicable security/privacy/trust services and policies that apply when processing info from other physical asset/DTs.
- **Visualization**: Knowledge visualizations.
- **Lifecycle**: Monitor status of the DT.

Step #4: Simulate and Prediction: Once an incident, trend or anomaly is identified (in the Understand and knowledge generation phase), FACTLOG should allow simulation of the behavior of the DT in the future and predict potential failures in the future. Simulation is performed based on root-cause analysis and using the existing behavior model (propagating the behavior of the system in the future using the new data).

Applicable Enablers:

- **Cognition:** Simulation and prediction services propagating the system's behavior with the new knowledge in the near future and identify potential anomalies.
- **Computation**: Cognition services will run whether at the cloud and/or edge.
- **Trustworthiness**: refers to the applicable security/privacy/trust services and policies that apply when processing info from other physical asset/DTs.
- **Visualization**: Simulation and prediction visualizations.
- **Lifecycle**: Monitor status of the DT.

Step #5: Decisions (optimization): After simulating and predicting the DT's behavior, robust optimization services will offer suggestions for improvements**.** Optimization services will propose a new state of the DT's behavior, which has to be validated using the simulation and prediction services. This feedback loop will consider the new DT's behavior inputs, simulate and predict its behavior in the system and assess the performance (is the problem solved? Is the trend fixed? Other?). If the solution is not validated, then optimization services have to run again and the feedback process continues.

Applicable Enablers:

- **Cognition:** Robust optimization services to identify new behavior parameters. Simulation and prediction services propagating the new (proposed) system's behavior in the near future and identify potential anomalies.
- **Computation**: Cognition services will run whether at the cloud and/or edge.
- **Trustworthiness**: Applicable security/privacy/trust services and policies that apply when processing info from other physical asset/DTs.
- **Visualization**: Behavior visualization.
- **Lifecycle**: Monitor status of the DT.

Step #6: Actuation: Once the optimized solution is validated, the actuation services will create the necessary messages to the physical asset in order to alert the behavior accordingly.

- **Communication:** DT with Physical Asset communication.
- **Computation**: Services will run whether at the cloud and/or edge.
- **Trustworthiness**: Applicable security/privacy/trust services and policies that apply when actuation is performed from DT to the physical asset.
- **Visualization**: Monitor the status of the actuation (confirmed or not, other).
- **Lifecycle**: Monitor status of the DT.

2.2 Application areas

The above model is modular. Using the DTs as a means for modelling any production entity, this ensure high degree of modularity and flexibility in performance monitoring and cognition deployment. The model supports all hierarchies of production systems, indicatively:

- The atomic asset (machine)
- The process line (network of connected machines in the process line),
- Factory as network of connected processes, workstations, faculties, etc.
- Supply chain as network of factories, logistics actors, etc.

FACTLOG can be deployed at different manufacturing contexts (process and discrete manufacturing). The consortium has studied various applications areas (from other projects, sources, etc.) which are the following (at the intra-factory level):

- Aligned predictive maintenance/ production scheduling
- Energy-aware machines (self-identification of optimal model of operation)
- Self-configurable production lines and machines
- Proactive behavior to risk management (e.g. Hazard analysis)
- At supply chain level:
- Connected circular supply chains – aligning material flows
- Aligned predictive maintenance/ production scheduling at supply chain level
- Merging deliveries/ On the fly collaborations in response to ad-hoc events/requests

- Proactive behavior to risk management (e.g. Hazard analysis)

The following sections present the pilot cases detailed business cases together on how FACTLOG operation model can be applied.

3 Business Cases

3.1 Waste-to-Fuel Transformer Plants: Pilot Case by JEMS

3.1.1 Reference Scenario

JEMS is developing and selling waste-to-fuel transformer plants. These plants are transforming any hydrocarbon-based waste into a high-quality synthetic diesel fuel. In these plants JEMS uses a chemical-catalytic 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, yard trimmings, cultivated plants, food leftovers, coal, crude oil, and others. The quality of the 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 on it. 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.

Note that such plants are typically installed in rural and remote areas, for various feedstock 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. JEMS intends to install more than 1,500 of such plants across the globe in short time, which would be impossible in traditional context.

Figure 3.1 SynDi Plant Installed in Canada

3.1.1.1 Context: The business case and As-Is process flow

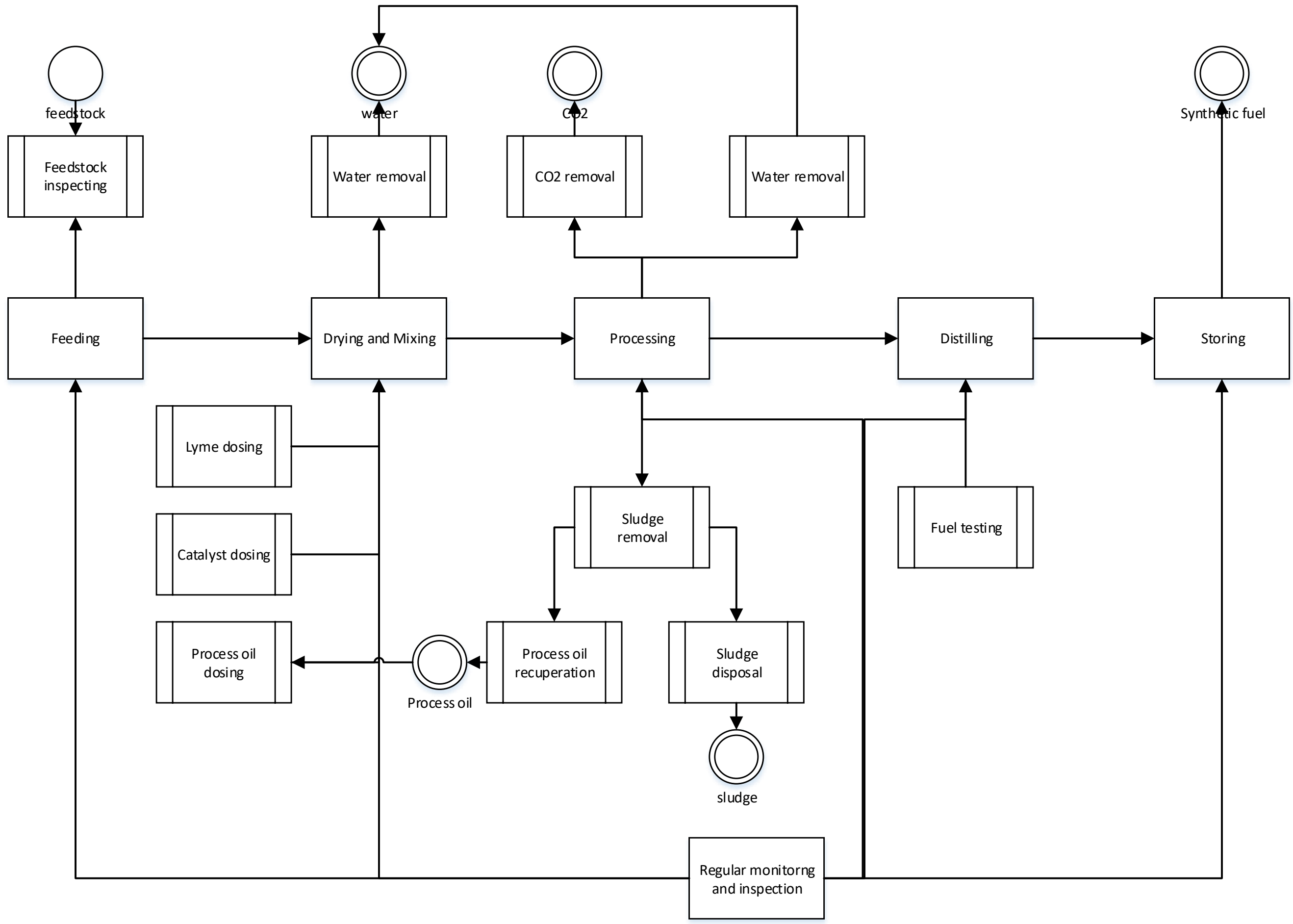


Figure 3.2 SynDi Plant Operating Process Flow

Feeding: The properly prepared feedstock (hydrocarbon) is being fed into the first process vessel, where it is mixed with process oil, lime, catalyst and heated up to 180ºC.

Drying and Mixing: During the mixing process in the first process vessel the fed input material is destructing into smaller particles, water is evaporating through the water distillation column and condensed afterwards to liquid.

Processing: The well mixed feedstock is pumped into the second process vessel where the material is heated up to 280ºC and fed into our turbine where the chemical reaction of shortening longer hydrocarbon chains to shorter hydrocarbons chains like diesel appears. The product of the turbine is then evaporating trough the diesel distillation column and condensed to raw synthetic diesel quality.

Distilling: The raw synthetic diesel is being redistilled in another distillation column to reach high-quality synthetic diesel fuel for the use in transportation or electricity generation.

As a sub-process or side-process of our plant all inorganics from the input material as well as added chemicals (lime & catalyst) are removed from the process in a continuous matter through our filter system to ensure a lean process.

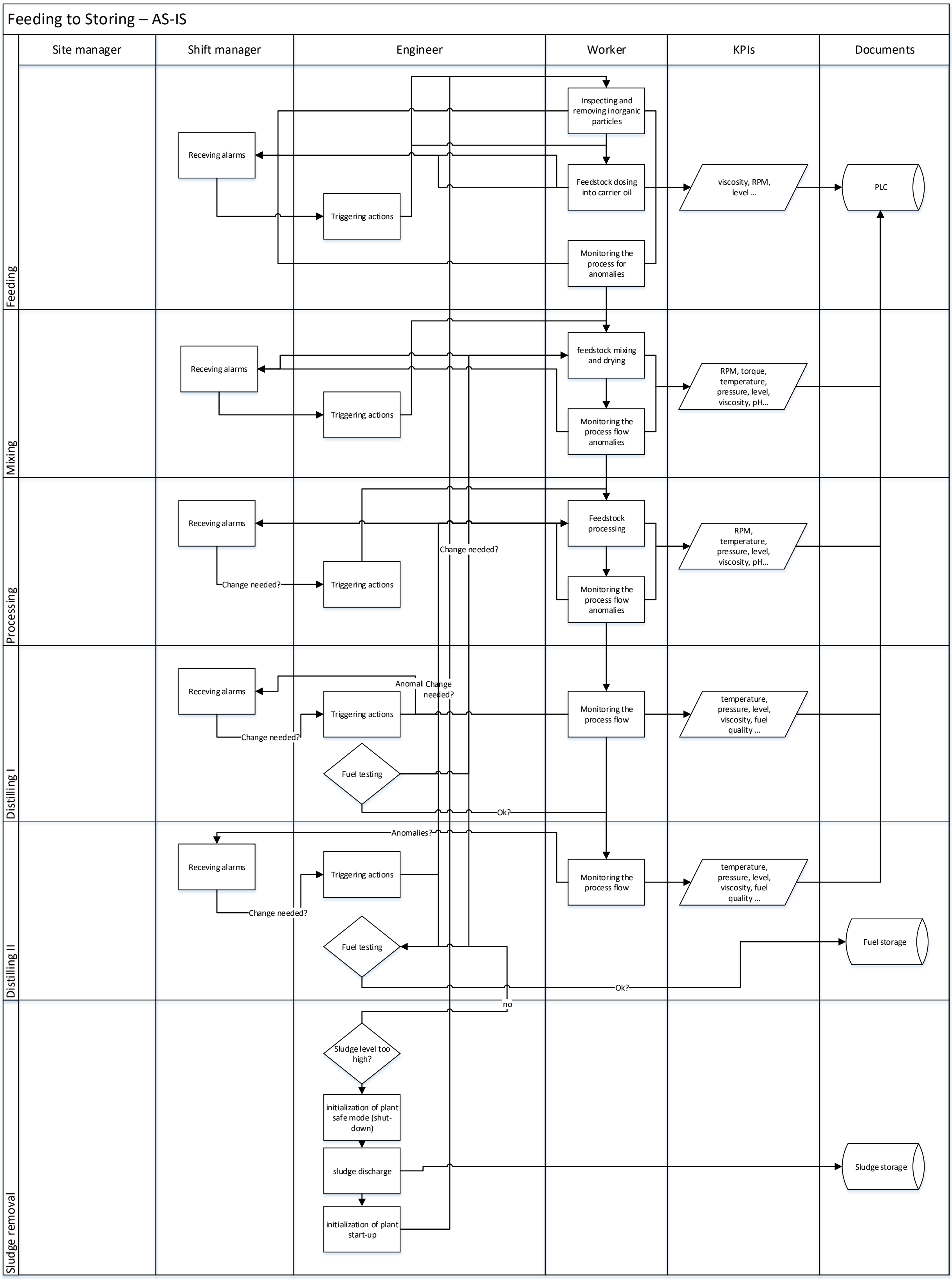


Figure 3.3 Feeding to Storing As-Is Scenario of JEMS

Detailed process description is available in the form of RACI matrix (**Figure 4.1** in the appendix section 4.1).

3.1.1.2 Existing Infrastructure (current IT infrastructure)

The current IT infrastructure allows data collection from 170 sensors (see Table 3.1), actions through 18 actuators and controllers, monitoring and updating the complete system. Basic analytics tools are in place, providing simple queries over the historical data and some basic rules of operation that have been encoded in controllers.

Table 3.1 Sensors and Actuators

Sensor Type	Quantity
TEMPERATURE	46
PRESSURE	16
VALVE RELATED	20
LEVEL IN TANK	8
PH LEVEL	1
FLOW	9
MOTOR POWER	5
MOTOR CURRENT	5
TORQUE	1
MOTOR SPEED	24
PUMP SPEED	3
START/STOP	11
OTHER TYPES	21
TOTAL	**170**

3.1.1.3 Pilot Specifications

The plant is already being equipped with more than 170 sensors and actuators. The current process is only based on close loops optimisation, mainly related to the existing controllers. We expect to run several cycles in FACTLOG. The first should be providing some basic optimisation scenarios based on the existing setups, the second should already provide feedback loops and revised plant sensors and actuators structure and the third cycle should test and validate the optimisation for various feedstock.

Example 1: Solving a clogging problem

When operating the SynDi plant it can happen, that due to the lack of an advanced process control system (AI) the system can clog (plug). In case of clogging the consequences can be critical in terms of keeping normal process parameters, or worse, losing control of the process and thus stopping the process to avoid further damage or mechanical failures. In case of such a failure the usual procedure is to:

(1) detect the clogged part of the plant;

(2) deciding if the plant can be operated during the unclogging process or has it to be stopped;

(3) unclogging the part of the plant, which can take (i) 15-60 min in case the unclogging can be done during the operation of the plant or (ii) 2-6 hours or longer if the plant has to be stopped and restarted after unclogging.

Example 2: Scenario of new input materials

The scenario of changing the process to a new input material requires a complex analysis of the input material regarding its calorific value, composition, humidity ect. In a second step the process parameters have to be adopted to the new input material to reach optimum production rates of the SynDi plant. The process of adopting the SynDi plant to a new input material can due to the above described actions take from 12 hours up to few days, furthermore, it requires great technical and chemical knowledge of the personal operating the SynDi plant changing the chemical process from one input material to another to at the end operating the SynDi plant continuously on a new input material.

The need for Cognitive Digital Twins

As described in detail in Section 3.1.1, the JEMS case focuses on 2 target problem scenarios:

a) Preventing the clogging of pipes by the waste material
b) Adapting the factory operational parameters to new input materials to ensure optimal processing

In this section we present the reference scenarios for the use of Cognitive Digital Twins, outlining the role of cognition as well as identifying the roles of the Digital Twins involved as well as the flow of information.

Scenario #1: Clogging of Pipes

Description: This scenario is, at its core, an anomaly detection problem. The operational status of the plant needs to be monitored and if a deviation corresponding to the clogging of pipes is detected an alert needs to be raised. The alert needs to provide enough information so that the root-cause – in this case the pipe that is about to clog – is identified to the plant operator along with the recommended course of action.

Actors: plant DT

Flow of information:

1. The operational sensor readings are passed as a data stream in real-time through the **message bus** and are validated against the **plant DT**. Deviations of the readings from expected behavior can indicate problems.
2. The likelihood of plugging is estimated by a detection system which can be powered by a **data-driven model** built by **analytics services**, by a expert-crafted **process model,** or a combination of the two.
3. The location of the clog is identified through root-cause analysis by the **simulation and prediction services**.
4. An alert is raised with the recommenced course of action based on the identified problem pipe displayed to the plant operator by the **visualization system**.

Scenario #2: Adapting to New Input Materials

Description: The JEMS plant can process a wide variety of waste (wood, plant trimmings, rubber, plastic…), but these can differ a lot in properties such as water content and density. The plant needs to be configured for processing of the material type.

Actors: plant DT

Flow of information:

1. Prior to its input, feedstock information is fed to the **reasoning engine** which recommends the plant parameter settings based on historical data.
2. The operational sensor readings are passed as a data stream in real-time through the **message bus** and are fed to the **plant DT**.
3. During operation while processing the new feedstock the **simulation and prediction service** runs tests of potential changes in the parameter settings and recommends tweaks based on the results and current performance.
4. All the recommendations along with explanations from the simulations are displayed to the plant operator through the **visualization system**.

3.1.1.4 To be process flow

The current process control of our process does not allow short time interfering into the process by understanding process correlated facts that would enable higher process control and production optimization, thus the integration of AI is of great importance. In the following lines the above written scenarios when AI is fully integrated and functional is described.

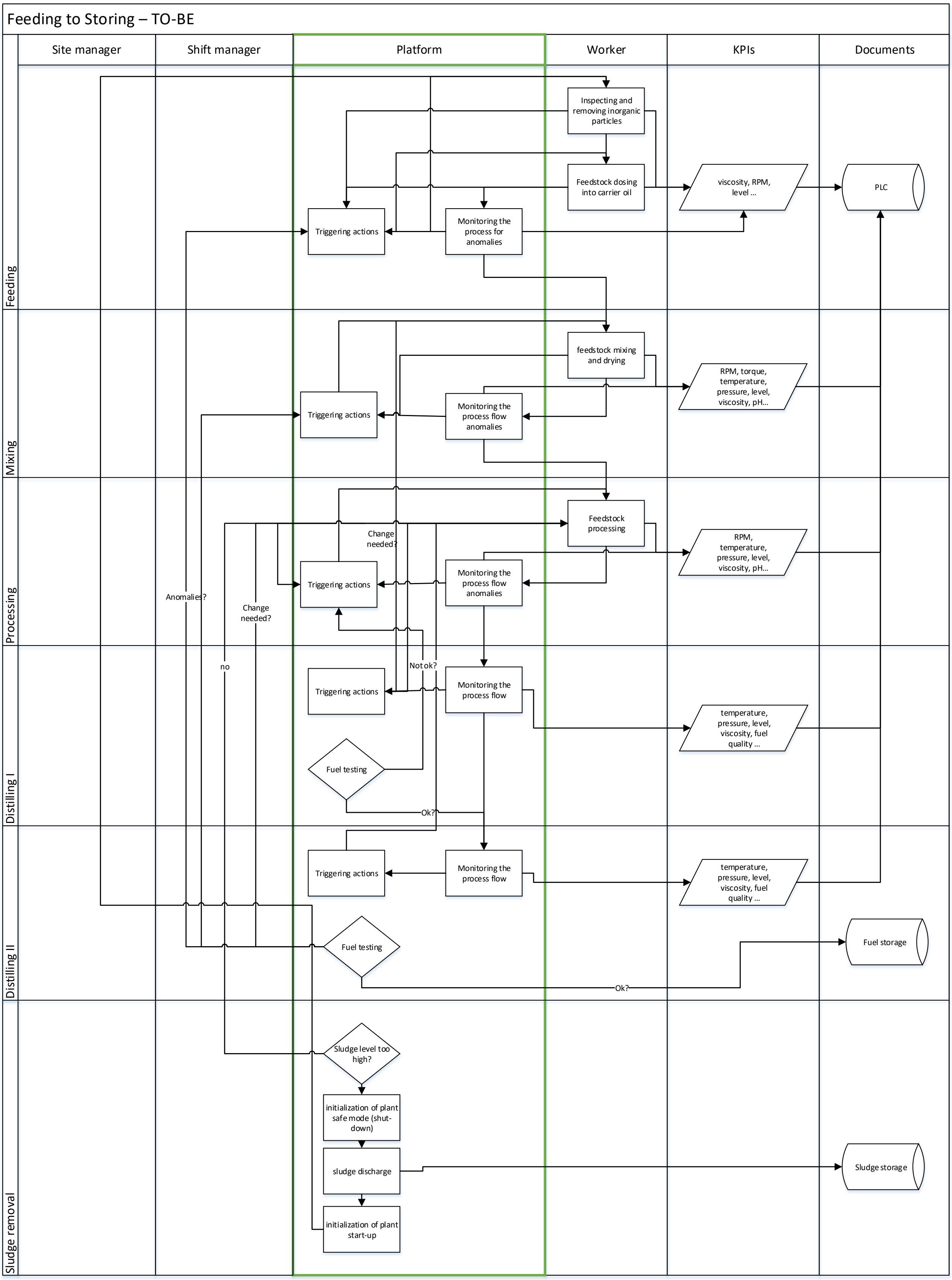


Figure 3.4 Feeding to Storing To-Be Scenario of JEMS

Example 1: Preventing a clogging problem (solution)

With the integration of AI on our SynDi plant, the clogging problem should enable a whole new way of monitoring the process parameters, and by watching and calculating the different process parameters preventing a clogging event. The scenario where the clogging event should be prevented by the AI part should be as follows:

Considering that a number of sensors are monitoring the process of synthetic diesel production, any anomalies like torque, viscosity, material flow speed and temperature can be used for a correlation model of our process enabling the AI system to learn and predict special events – like clogging. In comparison to a human interaction with the process which would include monitoring the process and reacting on possible anomalies in a time frame of minutes, the AI based system can monitor the process in time intervals of seconds and thus very fast detecting anomalies while reacting on in with different interactions within seconds. With such a system clogging events should be prevented in most of the times.

Practical example: in case the AI based system covers different parts of on the plant detecting process anomalies, which can be defined as possible cause for clogging, the system can interfere into the process by either starting a pump to speed up the flow of the process fluid, starting the filtering system earlier to extract inorganics from the process faster to prevent clogging or putting in some additional process oil to lean up the process fluid – each action depending on the spot of the SynDi plant and the specific characteristic of the process parameter.

Example 2: Scenario of new input materials

In comparison with a manual change of an input material to another and thus resetting all required process parameters on the SynDi plant to enable stable and continuous synthetic diesel production, which in normal circumstances can take up to few days, the AI based system should be able changing all required process parameters within seconds by adopting to a new input material smoothly in a continuous mode or at least fast without unnecessary interruptions of the process. Thus, the process of changing an input material to another should in praxis take no longer than 6-12 hours – depending also on the front-end system that has to be adopted mechanically as well to new mechanical feedstock parameters like specific weight, particle size, humidity etc.

Practical example: When deciding to run the SynDi plant with a new feedstock, the customer of the plant requires exact process parameters for his new feedstock that previously was tested on the SynDi center plant in Slovenia. The platform operator of the SynDi center is uploading the specific process recipe to the customers SynDi plant that ensures the customer’s plant is fully adopting to new process parameters for his new feedstock. From that moment on, the AI system of the SynDi plant is taking care of the process by monitoring all relevant and required process parameters for the new feedstock.

3.1.1.5 Impact and Sustainability

The main expectation from the FACTLOG project is the successful AI integration onto our SynDi plant for the transformation of hydrocarbons into high-quality synthetic diesel fuel. The AI integration is of essential importance for our process as well as business, because it will allow a fast market penetration of the SynDi plants combined with a self-controlled chemical process.

Impact

There are several main changes in the plant setup that are expected from the project for different types of feedstock:

- optimization in the main chemical process to achieve the same quality of fuel
- optimization of the energy consumption,
- optimization of the number of installed sensors and actuators; automation and feedstock flexibility,
- decrease the operation failures from 42% to 10%,
- decrease the operation costs from 8 experts/plant to 2 operators/3 plants,
- decrease CO2 due to optimized process from 25% to 35%

Sustainability

FACTLOG is essential for the plant operation and global scale-up. JEMS intends to use and upgrade the platform further with additional services. In addition, they are looking for long-term relationships with the interested partners in the consortium. JEMS already operates with Qlector and is expanding collaboration with NISSA.

3.1.2 KPI's

3.1.2.1 Description of KPI's

- Efficiency: this is overall efficiency of the plant that depends on one side to the type of the feedstock and from the optimized process parameters.
- Failures: the ide time of the process due to various failures of the plant
- The number of plant operators. These are employees needed due to the absence of the automation of the plant.
- Automation of the process. The number of sensors and actuators needed to optimize the process.
- Automation of sub-processes. Some of the sub-processes or related processes for example preparation of the input materials.
- Optimization of the process parameters. The optimization of the main chemical process.
- Reduction of mechanical parts. Mechanical parts can be significantly reduced and plant simplified due to the automatic plant behavior.

3.1.2.2 Baseline and target values for KPI's

Table 3.2 Baseline and Target Values for KPI's

KPI	Today	With FACTLOG
Efficiency	150 litters of fuel per hour	450 litter of fuel per hour
Failures	42% of the working time	10% of the working time
Plant Operators	8 per plant	2 per three plants
Automation of The Process	170 sensors	170+ sensors
Automation of Sub-Processes	Low control of technological sub-processes	High control of technological sub-processes
Process Parameters Optimization	Medium process parameters control	High process parameters control for better process control
Mechanical Equipment Specification	Practice based mechanical equipment specification	AI based mechanical equipment specification for higher efficiency

3.1.3 Initial Datasets

History data about the plant operation from the beginning of 2016 to first half of 2018 contained in two databases:

- P14029_Historian (size: ~10Gb)
- P14029 (size: ~60Mb)

Including data form 170 sensors and 18 actuators described with:

- tag (short sensor/actuator name),
- description,
- id of description in a language file,
- sensor/actuator group,
- datatype_id,
- measure_unit,
- additional fields related to representation and hardware.

And sensor/actuator values;

- sensor/actuator _values_day,

- sensor/actuator _values_hour,
- sensor/actuator values_minute,

Aggregates by day/hour/minute.

3.2 Oil Refineries Sector: Pilot Case by TUPRAS

3.2.1 Reference Scenario

Refineries are continuously producing many petroleum products such as LPG, naphtha, gasoline, diesel and fuel oil with high level of energy and utility consumption. Production plans are prepared with using LP models generated by the Planning Department. While these monthly based plans are preparing feed capacities of the production lines and legal specifications are taking into consideration. In order to follow the plan, the process plants' manipulative process parameters should be kept under control. For controlling these variables, 90 % of the process plants have Model Predictive Controllers (MPC). Beside product specifications, TUPRAS is trying to optimize the energy usage of the plants since the energy consumption is very high in refining operations. Energy Management Department is responsible for that purpose. Collaboration of Planning Department, Production Department and Energy Management Department is very crucial for operating a refinery. Therefore, emerging technologies for making production more sustainable and efficient is necessary. Energy and production quality aware decision support system for production scheduling can be one of the crucial parts in cognitive refinery approach. Basically, cognitive refinery will bring about energy-based optimization for whole production and intelligent decision making faster.

Since the refineries' whole processes are very complicated and creating a decision-making platform is very time consuming. In short, FACTLOG product have to select a product and its production lines into its scope for TÜPRAŞ refinery. In this project, LPG production lines will be optimized and targeted to minimize consumed energy and off-spec productions. LPG is abbreviation of "Liquefied Petroleum Gas" or "Liquid Petroleum Gas". In chemical terms, LPG is a combination of hydrocarbons that are mostly propane (C3) and butane (C4). This mixture is flammable and used as fuel in heating appliances, cooking equipment, and vehicles.

Crude oil is fed to the crude distillation units (CDU) and after this step, various different processes are following one another to obtain the final products. For example, CDU's distillation column's top product is feed of the naphtha splitter column and its top product is the feed of the debutanizer column. The products of the debutanizer column are light straight run naphtha (LSRN) and LPG. Since the separation yield is not 100%, some impurities like pentane (C5) is present in the LPG.

There are different process plants that LPG is being produced and purified. All these LPG product specifications are controlled with different processes in different production plants. These production units used in LPG production are described below; more details on the configuration of the LPG production units of the examined refinery are provided in Section 4.2 of the Appendix.

Debutanizer Column: Feed of this column is LPG and LSRN (C5) mixture. C5 content is a compound of gasoline so it should remain in LSRN to form gasoline and separated from LPG since it is an impurity for the LPG. LPG's C5 content is controlled by regulating the debutanizer column process parameters. There is a by-product of this separation consisting of small hydrocarbons like methane (C), ethane (C2) and some unrecoverable propane (C3).

This by-product goes to the refinery fuel gas ring to going to be used as fuel source for refinery furnaces.

Deetanizer Column: This columns' duty is removing and controlling C2 content in the LPG. Like in debutanizer column, its by-product that is a mixture of C and C2 goes to the refinery fuel gas ring.

DEA/Merox Column: To remove and control the sulphur compounds like hydrogen sulphur (H2S) and mercaptans (R-S). DEA process needs diethanolamine as an absorbent agent; it is reusable after a regeneration process with steam. Merox process needs caustic as an absorbent; it is reusable also after a regeneration process.

SHU Unit: Selective hydrogenation unit is removing 1,3-Butadiene in other words it is controlling 1,3-Butadiene amount in LPG.

LPG Recovery Compressor: Feed of this compressor is the fuel gas by-products of the LPG production process, which are otherwise fed to the refinery fuel gas ring. As mentioned, some of the C3 and C4, which are LPG compounds, are present in the fuel gas. Refinery fuel gas is fed to the LPG recovery compressor to restore the C3 and C4 content in the fuel gas before it is burned in the refinery furnaces. The unrecovered amount of LPG in this by-product should be regained when selling LPG is more profitable than using it as a fuel gas. Recovered LPG is sent to the LPG product pool. In order to keep the refinery fuel gas pressure and calorific value constant, if necessary, some Natural Gas (externally purchased) is added to the fuel gas. If LPG recovery compressor is running, there would be a need to add more Natural Gas. So, the decision to run LPG recovery compressor is made according to price ratio of LPG price/Natural Gas price.

3.2.1.1 Context: The business case and As-Is process flow

Refineries process crude oil, separate and crack it into its fractions to produce advantageous products like LPG and naphtha. The crude oil is first fed to the crude distillation units, these columns are typical multi draw-off distillation columns, and its cuts are like shown in the diagram below. The LPG is following to its own path to become sellable product.

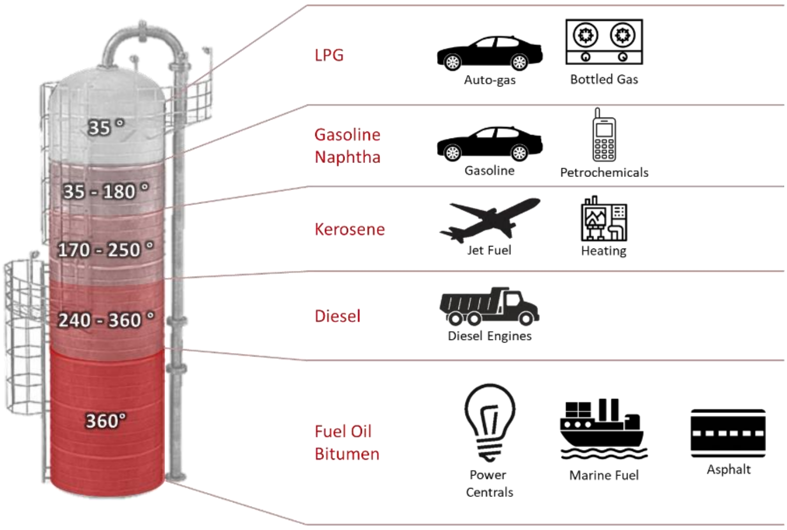


Figure 3.5 Crude Distillation Column and End Products

All of the LPG processes mentioned above, from crude distillation unit to final products' storage tanks, are controlled from different locations and by different engineers. The relationship between the production and storage tank qualities are controlled manually by the planning and production engineers.

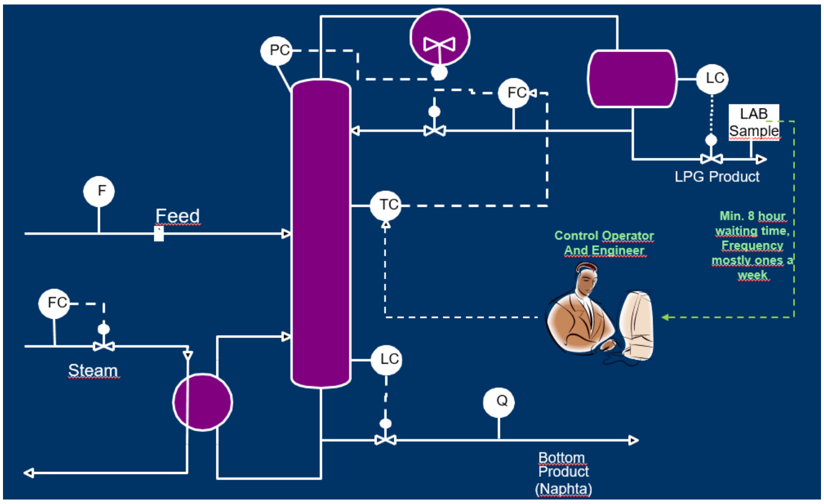


Figure 3.6 Sample Control Scheme of a Column

In normal operations, control operators are only responsible from their plants process parameters. Every plants' feed is changing with time, some of them is coming from tanks, others are rundown feeds. In other words, it is possible that some plant's product is another's feed or a final product.

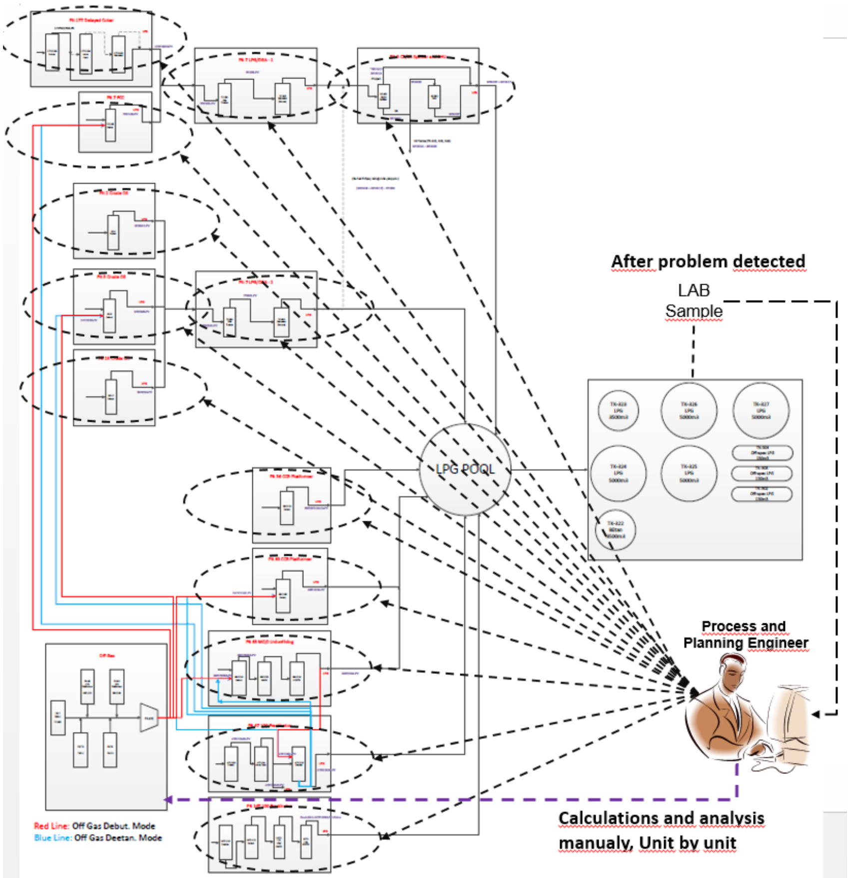


Figure 3.7 The Overall Loop to LPG Pool Quality Observation

In everyday operations, control operators have no information about their rundown feed or their product quality instantly. If there is off-spec production anywhere in the product line, and cannot be seen in the process parameters, then it cannot be noticed until the lab results come; this below quality production can be pointed out when the lab results are out. Unless the lab results are showing the quality of the product is good, the accumulation of this product on the storage tank might result in an unsellable (due to off-specs) blend.

Production is managed by production and planning engineers; the same holds for the product pool. If some anomaly occurs throughout the production line, its root cause is investigated by trying to detect anomalies at each step of the production separately. The responsible engineer looks into the related process parameters, laboratory test results and trying to point out which unit is responsible for under quality production. This multistep manual process results in slower detection of the problem so the solution action is also slow. While the engineers are trying to find the “rotten egg”, the off-spec production continues. The slower corrective action introduces low energy efficiency and process yield.
If an anomaly is identified in the process parameters of a specific process unit or in the product pool, the responsible engineers make decisions about what corrective actions should be taken with restricted information about the rest of the process line. This small perspective decisions do not allow keeping the production on its global optimum.

3.2.1.2 Existing Infrastructure (current IT infrastructure)

The current IT infrastructure allows data collection from all process plants. Process plants are monitored and controlled via distributed control system (DCS). There is a process data historian server for all process units and collect the data every 30-60 second. In addition, there are routine laboratory analyses for products, these analyses mostly on daily or weekly basis and results are collected by the Tüpraş Historian Database (THD) system. Every process unit has thousands of sensors and hundreds of actuators and controllers. The number of sensors considered to be used within the scope of FACTLOG is as follows. In the pre-evaluation stage, the number of sensors required to collect data is 190, which may increase in the following stages of the project.

Table 3.3 Present Sensor Types and Their Quantities

Sensor Type	Quantity
Temperature	26
Pressure	20
Valve Related	40
Level in Tank	9
Temperature in Tank	9
Flow	38

Sensor Type	Quantity
Start/Stop	11
Laboratory Analysis	30
Quality Inferantials	8
TOTAL	**191**

Legacy System

The product control & optimization and energy & utility optimization tools used for refinery production are not associated and there are different platforms. TÜPRAŞ is using optimization programs as follows:

- In-house developed Energy and Utility Optimization software,
- Commercial software for production planning and production optimization,
- Commercial software for model predictive controllers,
- Control systems software.

3.2.1.3 Pilot Specifications

During our initial analysis a number of interesting findings were derived leading mainly to anomaly detection, root cause analysis and optimization related needs and tools. The main pilot goal is to enable the creation of an energy and production quality-aware decision support system for production scheduling; hence, the need for early anomaly detection and subsequent energy-based optimization of the on-specs recovery process is evident.

The LPG production process is a complex process that involves different process units (corresponding also to different types of debutanizers) that receive a varied feed and process it in order to first remove carbon-based impurities (e.g. C_1, C_2, C_5 etc.). Next, the LPG progresses (depending on the type of debutanizer in the first process step) for further processing in different process units (LPG DEA units) to remove Sulphur-based impurities, until it reaches its final stage in the final LPG tank. Other process units that process by-products of LPG production (e.g., light gases such as C_1 and C_2) are also part of the LPG production process, since these by-products can be compressed (a decision also involving the price of LPG vs. that of natural gas) and thus transformed back to feed for the LPG production process.

In order to produce sellable LPG some specifications must be satisfied. Table 3.4shows the product specifications of LPG.

Table 3.4 Product Specifications of LPG

Total Impurities (C2 + C5)	Vapor Pressure	Pentane (C5)	Butadiene	Sulphur	Hydrogen Sulfide (H_2S)
5% mol/mol	1430 kPa	2% mol/mol	0.5% mol/mol	50 mg/kg	Negative

At any given point, it may be identified that the LPG within the final production tank has gone off-specs, i.e., the LPG in the final tank does not meet the desired quality specifications. This may be detected by refinery sensors or lab analysis, depending on the impurity. Anomaly detection functionalities are needed here to enable early detection/prediction of off-specs production and to facilitate root-cause analysis. Moreover, optimization needs to be called to examine the whole process in a global perspective and support recovery decisions by indicating which process units need to be utilized and under which operational scenario (e.g., increase of temperature at the top of the unit by a specified number of degrees), in order for the LPG within the final tank to recover to on-specs production within a given time-frame. Since this is a process that usually requires many of hours, optimization will need to be re-run if, for example, new labs results are obtained. Hence, it should always take under consideration ongoing values and corresponding projected outcomes, until on-specs recovery is achieved.

Hence, the focal point in this case for optimization is to enable the dynamic reconfiguration of the LPG production parameters for each distillation unit based on:

1. detected anomalies in the units
2. detected anomalies, or off-specs output of each unit,
3. off-spec output on the respective tanks and lastly
4. projected anomalies through the forecasted outcome based on simulation.

Having received input relevant to the aforementioned, optimization will be responsible for utilizing the process-driven models and data-driven models in order to be able to derive optimal (or near-optimal) proposals for settings of the participating production units in order to return to on-specs production within a given time-frame, taking under consideration the energy and planning KPIs and constrains provided by the case.

In order to enable the aforementioned, the FACTLOG system is expected to be able to (a) enable anomaly detection in various steps pf the process, (b) predict off-specs production, (c) facilitate root-cause analysis, (d) handle varied input and return the optimized settings from and to the remaining FACTLOG tools, and (e) perform the optimization tasks in a timely manner (projected solution generation at approximately 0.5-1 hour).

The need for Cognitive Digital Twins

The case of TUPRAS is summarized into the following three problems:

a) How to detect a trend in performance in each workstation making the best usage of data flows (from the workstation and external ones)?

b) Given an anomaly detection, how can I assess its impact and where is the optimal point of intervention to address this anomaly in the most efficient way?
c) When I find the point(s) of intervention, which actions should I perform, given the anomaly identified?

For each of the above problems we can create reference scenarios for the operation of Cognitive Digital Twins. For each of the scenario, we identify the actors and expected flow of information (from information sources, to cognition and optimization and finally visualizations to the end user).

Scenario #1: New Data Streams and Storing

Description: this scenario refers to how information is collected from different information sources and stored in FACTLOG in a meaningful way to create knowledge about the performance of the modelled assets/ processes.

Actors: All DTs (either asset and/or process)

Flow of information:

1. Information about Surfer, and other LPG constitutes is passing through the **message bus** coming from different sources (sensors, existing systems, testing results). This is done using data connectors created for each of the information source.
2. **Data abstraction services** are transforming information into a common format (using FACTLOG semantic model).
3. **Cleaning services** will store the preliminary processed data into the **persistence level**.
4. Advanced cleaning services can also be utilized using data-driven models (through cognition services).

Scenario #2: Anomaly detection

Description: Once information is collected, through Cognition, we can identify potential trends or even failures in performance of a DT.

Actors: Machine Digital Twin

Information flow:

1. Data streams from **machine DT** are evaluated from the **reasoning engine**
   - Against the **machine DT's** existing behavioral model.
   - If there is a data that is outside the model, we need to utilize the data-driven approach
2. **CEP services** detect a potential risk (probability for a failure). CEP services might be assisted by the **process models** which provide quality and other specifications of how the process/operation is run at the particular machine.
3. Through the **simulation and prediction services (root-cause analysis)**, we can propagate (predict) the behavior of the system considering the particular risk of failure of the machine. Initial prediction models will be based on historical data.
4. **Reasoning engine** provides as input the behavioral model of the machine.

5. As a result, the prediction and simulation services will provide the **necessary visualizations** to the end users.

Scenario #3: Impact assessment and optimized intervention (LPG quality)

Description: In case of a anomaly detection, FACTLOG needs to understand the affected DTs (assets and/or processes) and perform an impact assessment. This will lead on the identification of the optimal intervention points at DT level.

Actors:

a) Machine DTs: Digital Twins of the machines
b) Process DTs: A Digital Twin of the process as a network of inter-related machine DTs.

Information flow:

1. Data streams from the **machine DTs** are evaluated from the **reasoning engine**
    - Against the **machine DTs/ Process DTs** existing behavioral model.
    - If there is a data that is outside the model, we need to utilize the data-driven approach
2. **CEP services** detect a potential risk for the **machine DT** (probability for a failure?).
3. It is assisted by the **process models** which provide quality and other specifications of how the process/operation is run at the particular machine
4. In case of a potential anomaly, the **machine DT** informs (through DTs<->DTs messaging) the **process DT** in which it belongs to.
5. Through the **simulation and prediction services (root-cause analysis)**, we can propagate (predict) the behavior of the **process DT**, considering the particular risk of failure of the **machine DT**.
6. **Reasoning engine** provides as input the behavioral model of both the **machine DTs** and **process DTs**.
7. As a result, the **prediction and simulation services** will provide the **necessary visualizations** to the end users
8. **Optimization services** will make an initial suggestion for the best position to interfere (in which machine?) and the time estimations. **Optimization services** get the input by the **process models** on how the process works and other metrics.
9. The **simulation and prediction services** perform a propagation of the behavioral model of the **process DT** and **machines DTs** considering the proposed actions by the optimizer (see step 4)
10. If such solution is ok (against KPIs) then the proposed optimization is validated. If not, go to steps (7-8)
11. The **reasoning engine** is updated with new knowledge about the behavior of the **machine DTs** and **process DTs (**feedback loop from **Optimizer** to **reasoning)**

3.2.1.4 To be process flow

After the establishment of FACTLOG system, LPG process will be diagnosed from a single point. The overall looking to the process makes easy to process control operator to monitor whether there are any anomalies. Multivariate and advanced data analytics lying under this anomaly detection and corrective decision-making platform leads to take operator act fast, even before lab results are announced. After the FACTLOG the decision-making actions will changed to feedforward from feedback.

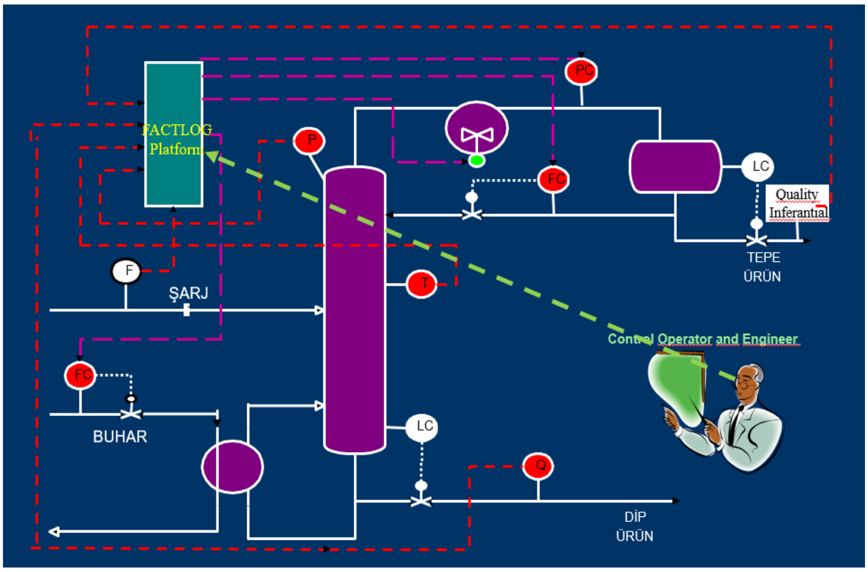


Figure 3.8 Proposed Process Control Scheme after FACTLOG Establishment

FACTLOG makes it possible for process and planning engineers to monitor the production process from a single platform. The fault detection property of this platform detects the responsible anomaly creator easily and offers decision support to facilitate taking corrective actions beforehand. The suggestion for the actions should be taken is considering the global optimum for energy and process efficiencies.

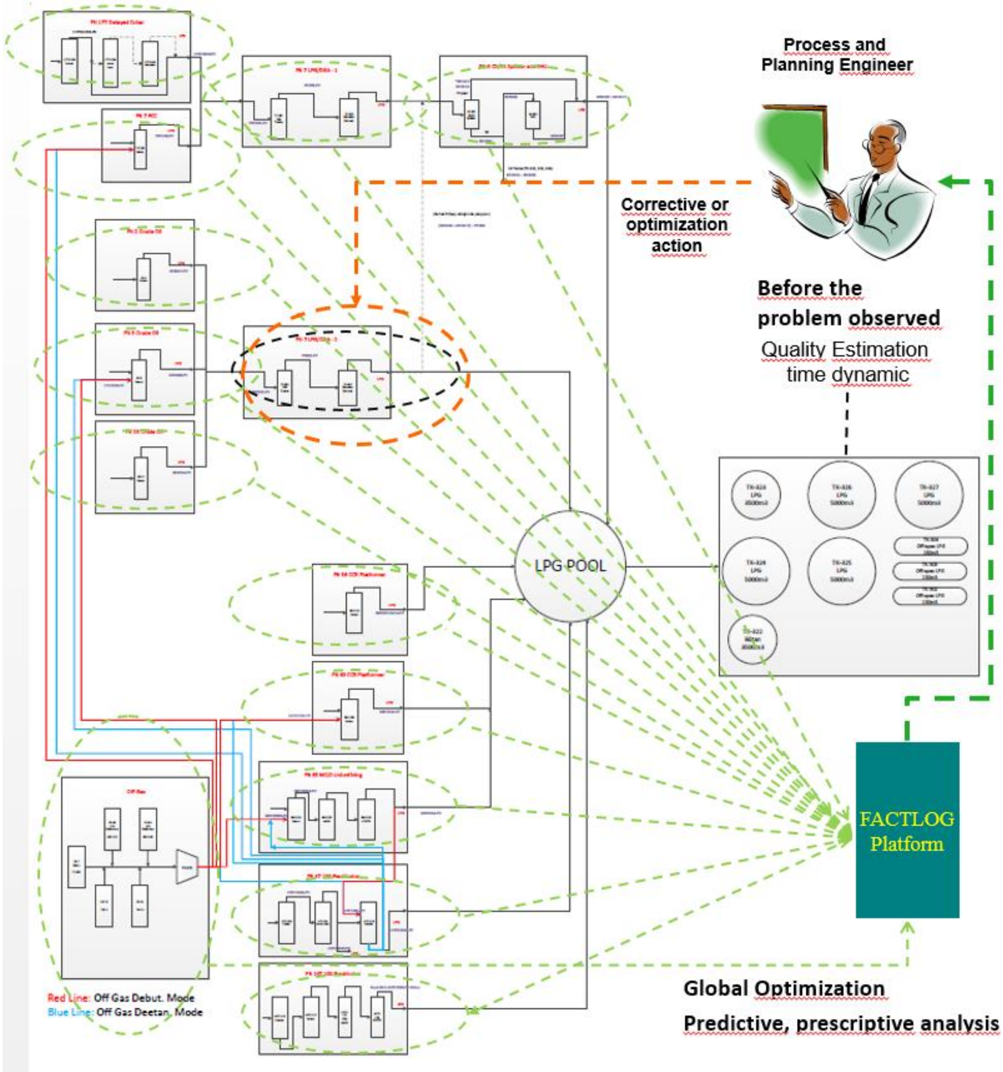


Figure 3.9 The Overall Loop to LPG Pool Quality Observation after FACTLOG

3.2.1.5 Impact and Sustainability

Impact: Connecting entire production in terms of energy and process optimization and creating a decision support system for the overall LPG production process will diminish the energy need of the refining operations. In addition, it is expected that the production quality of the LPG will increase with decreasing off spec production.

Sustainability: This project is focusing on the better LPG production with both quality and energy perspectives. The platforms and services will develop and will be useful for Production Planning and Energy Management departments. In terms of environmental sustainability is FACTLOG is trying to create a decision support tool to determine which selection of on-spec LPG production is more energy efficient. In addition to environmental aspect, sustainability of production itself is very crucial. The intention of TUPRAS is using the FACTLOG knowledge to scale up the project for other three refineries with additional supplemental services.

3.2.2 KPI's

3.2.2.1 Description of KPI's

It is expected that there will be improvements in three KPIs in LPG production. One of them is product quality, which is expected to increase from 80% to 85%.

The second KPI is the ratio of off-spec production, which is off-spec production; over total production. In current scenario, 30 % of the overall production constitutes off-spec.

The last one is response time for product failure. As have mentioned before, response time is significant to diminish the amount of off-spec production. It is aimed corrective actions will be taken in 12 hours with the help of FACTLOG.

3.2.2.2 Baseline and target values for KPI's

Table 3.5 KPI's Baseline and Target Values

KPI	Today	With FACTLOG
Efficiency	Product quality at 80% of target	Product quality at 85% of target
Off-Spec Product	Out of spec production 30%	Out of spec production 20%
Decrease Product Failure Response Time	24 hours	12 hours

3.2.3 Initial Datasets

Process modelling related parameters are;

- Flow Indicators*
- Level Indicators*
- Pressure Indicators*
- Temperature Indicators*
- Laboratory Results*
- Analyzer Result*
- Product Specifications
- Valve Openings *
- PID Controller Set Values*[7]

In relation to optimization, the datasets identified include data relevant to:

- Data relevant to the Set of debutanizer units (that require or don't require further processing)

[7] *These tags include time, value, unit and confidence information.

- Data relevant to the Set of LPG DEA units
- Data relevant to Quantity, C5 and Sulphur percentage in the LPG Pool
- Data relevant to Flow rates of raw feeds and Capacities per debutanizers
- Data relevant to Energy consumption per unit

3.3 Textile Sector: Pilot Case by PIA

3.3.1 Reference Scenario

Piacenza is an SME manufacturer of fine woolen fabrics, leader in the top segment of noble fibre fabrics for fashion and luxury markets. It is a supplier of fabrics to all world-leading fashion brand manufacturers (Zegna, Gucci, Prada, Louis Vuitton, Hermès among the others). Based in the Italian textile district of Biella, where all production is realized, it is one of the oldest textile industries of the world, founded in 1733 and from then on owned by the Piacenza family. Its production is fully performed in Italy and is completely integrated, from raw materials to finished fabric, with the only exception of the production phase of spinning, which is performed on its behalf by sub suppliers.

The organisation of the plant floor in Piacenza reflects the peculiarities of typical EU textile SMEs. In its machine fleet, especially in those parts of the process which have a direct impact on quality (i.e. finishing or weaving), machines coexist with ICT infrastructure tracing back to 10 years or more. However, in order to address the continuous pressure towards deep customization of fabrics and fast reduction of lot dimension, Piacenza has to dedicate significant effort in the renewal of its ICT infrastructure in order to collect and exploit newly produced data and towards optimizing its complex and inhomogeneous production. The participation in FP7 and H2020 projects has supported the development of an advanced SoA for data collection and management, integrating sensors, MES, ERP and a production scheduler into a single architecture based on Case Base Reasoning.

The Production Unit Controller (PUC) provides a first starting set up to be implemented based on previous cases of the same fabric or similar ones. During the production process, a continuous flow of information comes from the machines and, in case of unexpected events, necessary action suggestions are provided based on previous cases. Data collected by the PUC are also shared with the MES, ERP and production scheduler and with the factory coordinator, at company level. The structure is designed to be open to input from external sources of information, in particular with regards to the quality of input materials (e.g., yarn for weaving) and from internal sources, including incremental output (e.g., fabric quality) and performance data (e.g., machine speed) which can enrich the case database. The latter is critical in order to provide an action indication contextual with the event detection.

3.3.1.1 Context: The business case and As-Is process flow

Differently from what is generally expected, EU textile and clothing fashion and the luxury sector is living a golden age. Large conglomerate like LVMH – Louis Vuitton Group are increasing their turnover at a two-figure pace and the tendency is expected to continue.

“The paradox of Fashion? We have a single problem, in truth: that of not being able to fully satisfy the demand. We do not have enough manpower in our fashion department” as stated by: Bernard Arnault, CEO of LVMH, Louis Vuitton Group with 42,63 Billion Euro turnover in 2017 (+13% vs 2016) and counts brands like Christian Dior, Emilio Pucci, Givenchy, Kenzo, Loewe, Loro Piana, Marc Jacobs, Nicholas Kirkwood, Berluti.

The reason of this apparently unexpected success is the combination of the rapid growth of affluent rich people in the world and their specific request of European production, which combines high quality with sustainability, environment protection and ethical respect.

The textile value chain is characterized by the production and treatment of unfinished goods in B2B business relationships. It is very fragmented and distributed in a plethora of very small specialized subjects, usually sub suppliers, working for a few numbers of relatively larger fabric producers (wool mills), of medium dimension, mid-caps mainly. Especially in the case of high-value textiles, the design of new products' catalogues (collection) has recently brought about a subtle transformation of EU textile companies into "product-service" suppliers. Even the highest quality textile production would now become empty and worthless if disjoint from a close symbiotic collaboration with the stylists of clothing, in order to personalize fabrics (exclusive textiles) and to support them with the design of extremely customized products.

Piacenza is one of the few undisputed worldwide leaders in high fashion fabrics and accessories production, with a competitive strategy focused on the maximum differentiation of the product, in terms of raw material choice, style, and colour (Figure 3.10). Piacenza turnover is close to 50 million Euros, with more than 200 employees (increased of 25 people in the last 12 months). With an average industrial sale price around 70 Euro per meter, corresponding to more than 3.000 Euro per coat at retail price, and a design proposal of more than 1.000 new styles per year, Piacenza is supplier of all leading fashion groups (Louis Vuitton group, Kering, Group, Burberry's, Gucci, Prada, Zegna, Hermès, Dior, Hugo Boss among the others). This favourable competitive position is enforced by design know how and quick flexibility to customer requests, where the offer of new, customized and/or exclusive fabrics is made in close cooperation with fashion stylists. This cooperation with clothing designer has become so close that hundreds of exclusive fabrics are specifically realized for fashion leading industries every year. Currently more than 35% of the production is based on exclusive customised design made for fashion stylist, and this tendency is constantly increasing. The sales are equally distributed in Italy and abroad but considering the high percentage of export of Italian fashion houses, the final retail market of Piacenza products is mainly abroad.

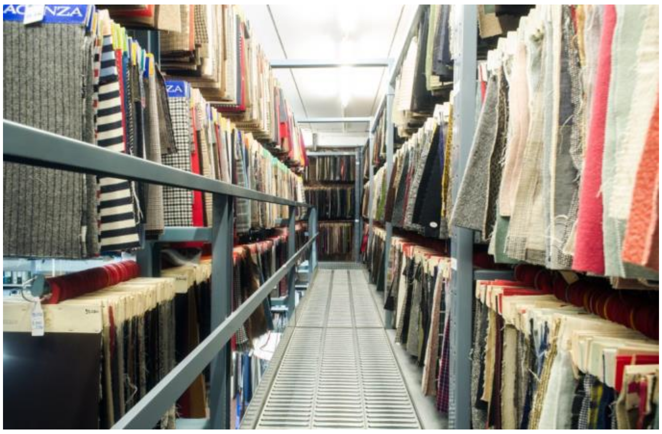


Figure 3.10 Piacenza New Collection Design Show

Piacenza strategic target is not to increase quantity but average price, enforcing market barriers based on design; know how, personalized service and sharp delivery.

The production is based on the vertical integration of the production, starting from the raw material selection, quality control and purchase, up to the delivery of the finished fabric to fashion houses, ready for clothing production (Figure 3.11).

Figure 3.11 From Raw Material to Final Product

This sector is characterized by some very specific peculiarities:

- extremely high number of product variables
- deep customization
- hardly predictable demand
- length of production cycle
- physical prototyping and sampling
- fragmented distribution
- inefficient vertical information transfer
- fast decrease of average lots

Figure 3.12 depicts the current situation.

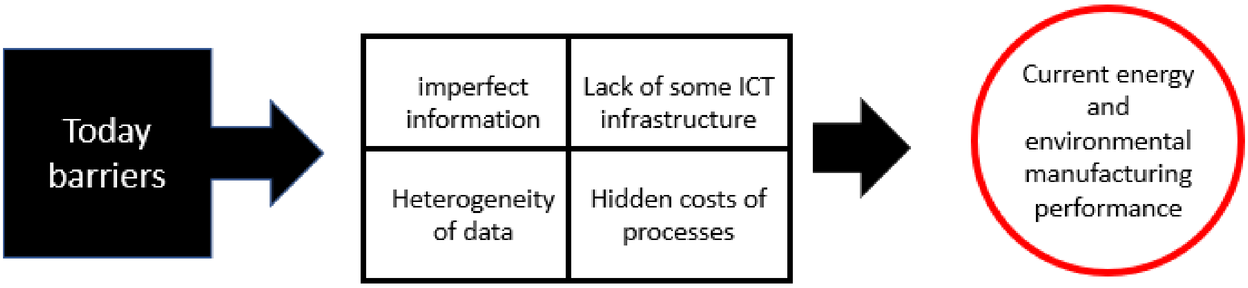


Figure 3.12 Piacenza As-Is Workflow

The combination of these aspects, which appear in direct contrast within each other, leads to a very complex production planning management, which must properly balance the request of a very fast and demanding market with the length and rigidity of a complex and long value chain.

3.3.1.2 AS-IS situation

With more than 70 production passages, the production of fabrics is a very deep and complex manufacturing process, which starts in the countries of origin of the natural fibers used for fashion fabrics (cashmere, vicuna, alpaca, mohair, silk, wool, linen, etc...) and can be summarised into three main changes of material status: raw material → yarn → fabric. Piacenza production can be summarised by the following simplified scheme:

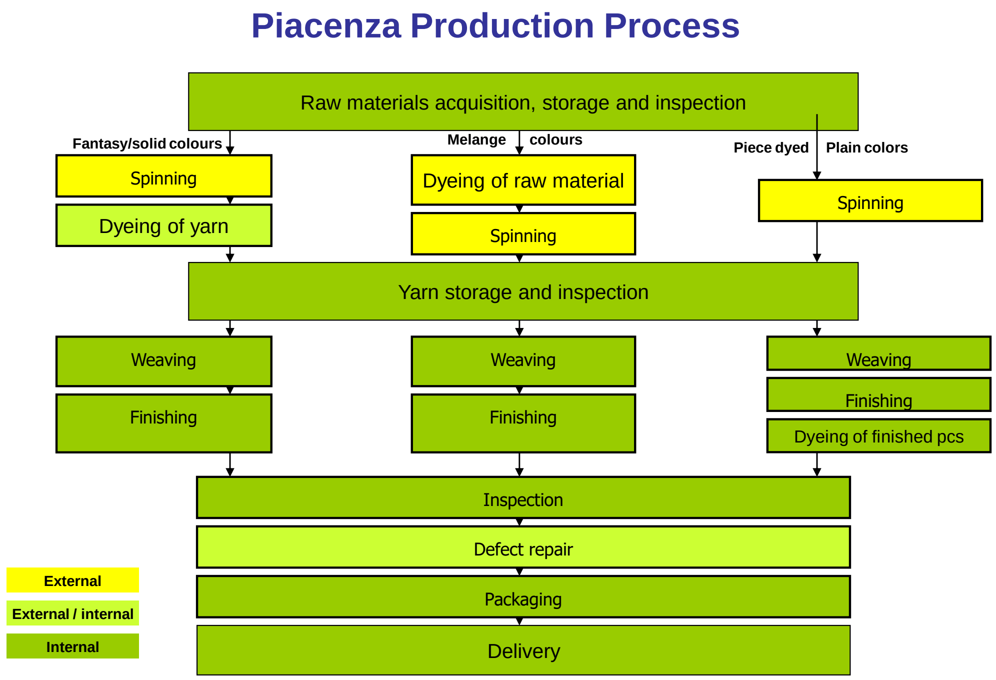


Figure 3.13 Simplified Production Workflow of Piacenza

The current IT infrastructure will be described according to each main step of the production process.

Inspection, defect repair, packaging and delivery are processes carried out mainly manually, hence they are out of the scope of this project.

Raw materials acquisition, storage and inspection.

Raw materials used by Piacenza are only natural fibers, directly selected in the markets of origin. The quality of the fabrics of Piacenza is directly related with the high quality of the noble fibers used (cashmere, vicuna, alpaca, silk, linen and ultrafine wool, only to name the most important ones. Because on this, the selection is directly managed by the company. Being limited towards an increasing demand, raw materials selection is a critical aspect of Piacenza's production and its careful management will become even more critical in the future. Because of the shortage of high-quality raw materials, the inspection process is strict and implements counterfeiting procedures.

Cashmere suppliers, for example, tried to mix ultrafine wool, which can be discovered by electronic microscope analysis, able to separate the goat (cashmere) from sheep (wool) fibers. More recently suppliers have tried to mix cashmere with yak, whose fibers are hardly detectable. To prevent this unfair action Piacenza has developed a new process with C.N.R. (Italian National Research Centre) based on DNA analysis, which can detect also yak fibers.

From the selection to the purchase and receipt of raw materials the lead time can reach 60-90 days, depending on the market of origin (Asia for cashmere and silk, South America for camelidies, Australia and New Zeland for ultrafine wools), which can only be reduced by very expensive air transport.

Moreover, the seasonality of raw materials sourcing, due to the natural lifecycle.

Finally, the sourcing process is subject to currency price changes, since all raw materials are quoted in USD.

In relation with the complex combination of all these aspects Piacenza must manage to anticipate raw material purchases, able to cover at least one-year production needs, with the related financial problems of invested capital and risk of wrong forecast mix.

IT infrastructure: warehouse accountability, administrative/purchasing accounting software. This IT infrastructure are out of the scope of the FACTLOG project.

Spinning.

This process involves all the operations necessary to transform raw materials into yarns. It stars with raw material washing, mixing and (eventually) dyeing. Without going too much into details, the process can be classified in carded and combed spinning, in relation with the dimension of the yarn. The first one for larger yarns while the other is for thinner ones. Because of the large dimension of the machineries and the scale of production, Piacenza has dismissed internal spinning in the seventies, and it relies on the support of local suppliers, which transform raw materials of Piacenza property into yarn. The time needed to transform raw materials into yarn goes from 15 to 30 days, when the production capacity is available. Due to shortage of qualified external spinning capacity, this timing must be taken into careful consideration and the production must be booked in advance.

IT infrastructure: not available, the process is outsourced and out of scope for the FACTLOG project.

Weaving and Finishing.

Usually the transformation of yarn into fabric is identified with weaving but this is a wrong and very simplified idea.

To create an orthogonal fabric, it is first necessary to prepare the warp, which might reach thousands of yarns per meter, in many cases of different colours.

Figure 3.14 Fabric Warp on A Loom Machine

Warping is only partially supported by machineries and requires up to 8 hours to prepare a complete warp for weaving, independently form the length of the warp. Because of this reason, the warp length per loom is a key performance indicator of weaving lots. In some cases, it is possible to use the same warp for different fabrics, by changing the weft. The "chainability" of similar fabrics is a parameter to be taken into proper account for weaving scheduling.

Weaving is the core part of the process, where the loom crosses warp and weft yarns. The speed of the loom can be optimised in relation with the resistance of the yarn to traction, which is related to the raw materials used and the spinning process (carded or combed). Contrary to the common expectation, thinner yarns produced by combed spinning are more resistant than the larger ones produced by carded spinning.

But the most critical part of the process comes after spinning and is called finishing, which is the process giving to the surface of the fabric some characteristics affecting the its touch feeling. The first finishing phase is the shrinking, where the fabric is subject to wash and pressure which causes its shortening, of around 20%, and thickening. This step is followed by drying and brushing. This last one is aimed at extracting the fibers from the surface of the fabric to sweeten its hand touch. Finally, the extracted fibers are cut, oriented and steamed to grant dimensional stability.

After weaving and at the end of the process all the fabrics are manually inspected to detect and fix the eventual defects. In consideration with the high price of Piacenza products this inspection is mandatory and no automated process has yet proven to be able to substitute human intervention, because of the extreme variability of designs, colours and of natural fiber aspect.

The whole process to transform yarn into fabric requires from 4 to 8 weeks and involves small machineries (for example looms), and large ones (for ex. dryers), with different lot dimensions and optimisation parameters. The combination of a time-consuming process, an erratic demand, various optimisation parameters and a very wide design offer makes Piacenza production a very challenging process to plan and schedule.

The whole process is carried out (with the exception of spinning performed in the neighbourhood), in Piacenza facility in Pollone, in the North of Italy. Because of this reason

Piacenza fabrics can be certified with EU preferential certification of origin, requiring two substantial transformation performed in EU (raw material → yarn → fabric).

IT infrastructure: MES (involving the set of PLCs to manage production machineries), ERP.

3.3.1.3 Pilot Specifications

Cognitive production planning

Piacenza production is exposed daily to changes in production planning to respond to new orders from fashion clothing customers. The constant overlapping of new design sampling and regular production introduces an additional level of complexity to the production planning and scheduling, which needs to face a mass of data hardly manageable by human operators in an efficient way.

At present, there is a person in Piacenza's staff, who evaluates the incoming orders using a method based on resource availability in the warping and weaving departments and on materials availability. At present, Piacenza's ERP system enables a detailed analysis of the resource availability through a warping/weaving GANTT consultation. There is an on-board machinery system, which constantly updates and eventually re-adjusts the GANTT, according to the events that happened on the machinery itself. In this process, there are technical and qualitative variables that can interfere with the standard production flow, in favour or not. For example, a lot that generates many breaks in the weaving phase hinder the productivity. On the other side, a good quality of the lot material allows to use a higher weaving speed and enhance the performance of the machinery. At present, we focus mainly on the departments that affect the delivery date agreed with the customer, while we do not manage anything structured after these steps. We make a rather generic analysis on crossing lead times of the other production steps, on the base of rather standard times-cycle, differing not so much from product to product. Nowadays the finishing/dyeing process is becoming more and more important and various in its peculiarities (up to each single colour), so the need of its controlled monitoring becomes essential.

The pilot aims at increasing the capacity of Piacenza to respond to the erratic market needs, combining flexibility and production optimization to reach the best possible results.

In relation to optimization functionalities in the Piacenza case, the initial analysis yielded a number of findings highlighting the optimization needs and tools. The main pilot goal is to enable the creation of an energy-aware decision support system for production scheduling; thus, there is a clear need for adoption of appropriate job scheduling models and design of efficient algorithms.

The fabric production process in the PIA case is a sequential process that involves specific and different steps (corresponding to the flow from yarns to fabrics) performed in different sets of machines with the support/involvement of a set of workers. Initially the stored yarns are transformed into fabrics by weaving, performed in looms. The fabrics produced are forwarded to finishing process that consists of several consecutive sub-processes, each one performed on a dedicated set of machines. The sequence of machines a yarn has to go through in order to be transformed into a final product (ready for shipping) is strongly depending on the product type, for first the kind of expected "hand touch", and its relation with all other products currently being produced or in queue, leading to challenging combinatorial optimization problems, such as job scheduling problems on parallel unrelated machines and/or flow-shop environments.

At any given point of production, it may be identified that: (a) a loom is malfunctioning/breaks down, (b) a yarn is broken and requires temporarily halting the machine and repairing the breakage (c) a faulty batch of yarns is selected for processing ending up in breakage (d) a high priority order arrives that needs to be handled. On that account, optimization needs to examine the whole process in a global perspective and support the production scheduling process taking under consideration the current and upcoming orders, proposing efficient algorithmic methods, indicating which orders should be processed in what order and on which machine, so as the products to be ready on time for shipping. Since this is a dynamic process, usually involving many machines and various orders which are processed in parallel, especially in cases with significant delays or new orders arrival a re-optimization procedure will be probably very useful so as to always take under consideration the varying parameters and the corresponding production schedule outcome, until production of all fabrics is conducted within a timely manner, utilizing the least amount of energy and the overall costs.

Based on the above-mentioned, the focal point of optimization framework is to enable the dynamic/online scheduling of the fabric production process, executing at each time period, the already released orders with respect to their deadlines and sequence-dependent setup times, so as to minimize the total cost (or another set KPI e.g. energy) based on:

1. Detected anomalies in the machines involved (e.g. looms)
2. Detected anomalies, issues in the intermediate steps of production (e.g. breakage of yarn)
3. Scheduled maintenance activities
4. Relation and commonalities between orders under production and on queue
5. Scheduled deliveries of finished products, and
6. Energy consumption considering every production step.

Having received input relevant to the aforementioned, optimization is responsible for utilizing the process-driven models and data-driven models in order to be able to derive optimal (or near-optimal) proposals for scheduling of the orders into the respective machines for the involved production steps and infrastructure, taking under consideration the energy and performance KPIs, as well as the constrains provided by the use case.

In order to enable the aforementioned, the FACTLOG system is expected to be able to (a) incorporate anomaly detection, (b) handle varied input and return the optimal schedule from and to the remaining FACTLOG tools, and (c) perform the optimization tasks in a timely manner (e.g., generating production schedules in a weekly manner).

The need for Cognitive Digital Twins

The case of PIA is summarized into the following three problems:

a) How to detect a trend in the performance of each machine (e.g loom) making the best possible usage of data flows (both from the workstation and external ones)?

b) Given a detected anomaly, how can I assess its impact on the production and therefore produce resource – aware aspects in production scheduling?

For each of the above problems we can create reference scenarios for the operation of Cognitive Digital Twins. For each reference scenario, we can identify the actors and the expected flow of information (from data sources, cognition, optimization and finally visualization to the end user).

Scenario #1: New Data Streams and Storing

Description: this scenario refers to how FACTLOG collects information from different sources and stores it in a meaningful way, so as to create knowledge about the performance of the modelled assets/processes, while taking under consideration the current focal point of weaving.

Actors: All DTs (either asset and/or process)

Flow of information:

1. Information about Looms' Status, Energy consumption, Orders, products, sequence of execution, is passing through the **message bus** coming from different sources (sensors, existing systems). This is done by using data connectors created for each information source.
2. **Data abstraction services** are transforming information into a common format (using FACTLOG semantic model).
3. **Cleaning services** will store the preliminary processed data into the **persistence level**.
4. Advanced cleaning services can also be utilized using data-driven models (through cognition services).

Scenario #2: Anomaly detection and new production plan formulation

Description: Once information is collected, based on FACTLOG's cognitive capabilities we can identify potential trends or even failures in the performance of a DT, and consider/incorporate them in our production plan formulation.

Actors: Machines Digital Twins, Process Digital Twins

Information flow:

1. Data streams from **loom / weaving / finishing DTs** are evaluated from the **reasoning engine**
    a. Against the **loom / additional machines DT's** existing behavioral model.
    b. Against the order that needs to be processed and **Process' DTs for weaving and finishing** behavioral model.
    c. If there is data outside the model, we need to utilize the data-driven approach.
2. **CEP services** detect a potential risk (probability for machine to fail or to break a yarn in the course of the scheduled order). CEP services might be assisted by the **process models** which provide quality and other specifications of how the process/operation is run at the particular machine.

3. Through the **simulation and prediction services (root-cause analysis)**, we can propagate (predict) the behavior of the system considering the particular risk of failure of the machine. Initial prediction models will be based on historical data.
4. **Reasoning engine** provides as input the behavioral model of the machine.
5. As a result, CEP services inform Optimization about looms' status (GO/NO GO on all Machine DTs for the given Order)
6. **Optimization** provides a new schedule taking under consideration the machines' status.
7. The **simulation and prediction services,** utilizing the **process DTs,** project the schedule of the order derived from the **Optimization Output (Schedule based on delivery date order MAINLY)** and remaining data can propagate (predict) the behavior of the system considering all orders to predict possible outcomes of energy related information and usage per incoming order to be processed.
8. **Reasoning engine again** provides as input the behavioral model of the machines
9. As a result, the FACTLOG system will use Analytics, Prediction, Simulation and Optimization services to provide the **necessary visualizations** to the end users that will begin the production (The Production Schedule with New order) and proceed to execute it.
10. In case a yarn/loom breaks, then restore feasibility of the production plan if necessary. (Go to #2)
11. The **reasoning engine** is updated with new knowledge about the behavior of the **Loom DTs, Finishing machines DT** and **global production DTs** (feedback loop from **Optimizer** to **reasoning**).

3.3.1.4 Expected situation

Expected changes about the data collection process

Starting from the data coming from the two main existing phases today (warping and weaving) and already monitored with great attention, we should build up a similar scenario for all the production processes in the finishing department. Each of them must be represented in a working cycle tailored on each product/article. This should be done in order to give an immediate vision of the production advancement to the production-planning manager, so that he/she can foresee possible delays, and act accordingly. The manager should be able to identify future bottleneck in special machineries, going through some production steps in advance, so to avoid delays or plan the use of further resources, everything is possible to avoid lead-time process expansions. We will feed an instrument (scheduler/planner) with a complete set of data, with the aim to get a GANTT vision for each production step. This one is going to use the previous GANTT chart and “feed” it with the new data, in order to get a new and more accurate one. The latter will give an overall vision, which will be useful for the resource optimization, but it also takes care about giving information/alarms on possible qualitative issues, using the rules of the internal process of the company.

Expected changes about the production process

The implementation of the pilot is expected to positively affect Piacenza production planning and scheduling in terms of service, e.g. reduction of delivery timing and of production defects, and resource optimization, e.g. direct cost of manufacturing, energy, water and raw materials waste reduction.

The pilot is expected to provide Piacenza planning and scheduling managers with an instrument able to rapidly suggest them the best solution to balance the different and often conflicting instances of customers and production, exploiting all the sets of data available and input stemming from cognitive twins as well as process driven and data driven models at the moment as regards current production and machineries state on one side, based on an a model evolving on the experiences and learning from the past production on the other.

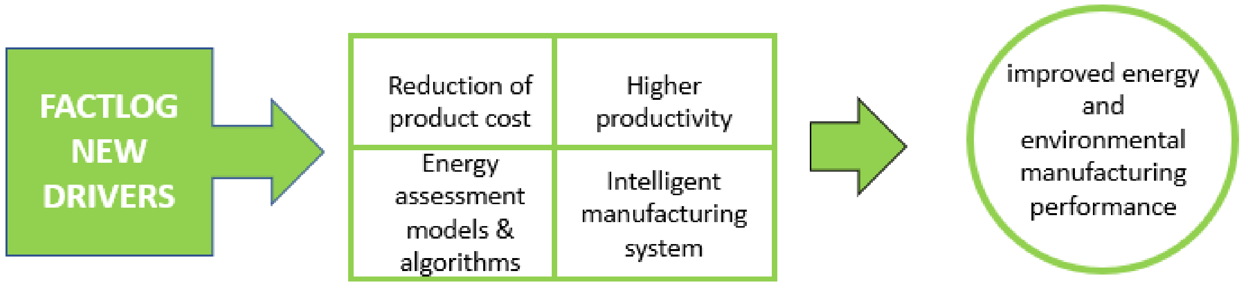


Figure 3.15 Piacenza expected situation

Potential benefits of applying FACTLOG solution to the use case

- Determine the optimal allocation of production operations to a set of workstations, with respect to predefined constraints (e.g. cost impact).
- Minimize the number of workstations given a specific cycle time and specific constraints.
- Minimize the idle time of each workstation eliminating possible bottlenecks
- Potential increase in productivity and decrease in cost.
- Propose an alternative production line plan that is cost, production efficient in case of a failure.

3.3.1.5 Impact and Sustainability

Business Impact and Sustainability will be represented by the following table, that describes business objectives, and for each objective its impact and effect on several aspects (i.e. cost, efficiency, quality, flexibility, innovation, sustainability). Two different tables describe impact for the weaving and finishing departments, namely.

Table 3.6 Impact and Sustainability for the Weaving Department

BUSINESS OBJECTIVE *expected for the Business Scenario/Use Case*	**DESCRIPTION**	**IMPACT** *of the business objective for the company*	**EFFECT IN VALUE[8]** Rate from 1 to 5 (being 1 no significant impact and 5 very high impact)	
In Piacenza **weaving department** brand, new machineries coexist with old ones, which are still satisfying the needs of current production. The objective the pilot is to maximize the exploitation of the current production infrastructure, to reduce the costs, to increase the efficiency of the department and to increase the quality by reducing the defects.	The main parameters which affect the optimal production management of weaving are the length of the warp per loom and the speed of the machine. The long preparation of each warp, independent from its length, affects strongly the department exploitation and causes queues of loom preparation in cases of contemporary warp changes, with the related decrease of department manufacturing capacity exploitation. The speed is related with the careful tuning of the machinery in relation with the specific resistance of the yarn. In case of stop the direct timing to repair the broken yarn and to restart the loom is added with the one of the queues to wait the first available operator to carry out the job, especially in case of contemporary stops.	Currently Piacenza has to exploit external weaving support in peak periods due to the low manufacturing capacity exploitation. The pilot is expected to increase it and to decrease the direct costs per meter and the use of external weaving capacity in favor of internal one.	**Cost**	5
			Efficiency	5
			Quality	3
			Flexibility	3
			Innovation	2
			Sustainability	2

[8] These six categories of effect proposed, comes from the EU Project COMVANTAGE*, where the aspect at the business process level in which an improvement is expected to occur are:

- **Cost**: ICT capabilities can contribute to cost reduction in various ways: Automation and standardization of tasks, qualify workers faster and better, inventory and stock management improve and integrating the suppliers into its customer´s ICT.
- **Efficiency**: ICT capabilities can contribute to improve efficiency in various ways: Improve availability and efficiency of machines, enabling easy access of maintenance employees to relevant information, facilitating identification and analysis of problems, shortening the response time to malfunctions, optimization of the machine´s activity scheduling and automating decisions regarding maintenance and production activities.
- **Quality**: ICT capabilities can contribute to improve quality in various ways: Supporting the creation of the characteristics of the product or service, understanding the requirements that the product or service should fulfil, increase the feet to the specification of the product or service (decrease errors), improve the communication of the involved parties in the creation and delivery of the product or service, making information about the customer´s order available from initiation to completion, facilitating transparency and early identification of deviation from desire outcome, adapting to the changing need of customer's and the constrains of suppliers, facilitating better understanding of customer´s needs and generating inside into de customer´s tacit as well as explicit needs and requirements.
- **Flexibility**: ICT capabilities can contribute to improve flexibility by product and service customization to adapt to market changes and customers preferred options at designed stage.
- **Innovation**: ICT capabilities can contribute to improve flexibility by product and service customization to adapt to market changes and customers preferred options at designed stage.
- **Sustainability:** ICT capabilities can contribute to improve sustainability by reducing carbon footprint in three ways: Reduced paper usage, reduction of energy consumption and reduce fuel consumption in distribution.

Table 3.7 Impact and Sustainability for the Finishing Department

BUSINESS OBJECTIVE *expected for the Business Scenario/Use Case*	**DESCRIPTION**	**IMPACT** *of the business objective for the company*	**EFFECT IN VALUE**[9] Rate from 1 to 5 (being 1 no significant impact and 5 very high impact)	
In Piacenza **finishing department** very large machineries (for example the dryers) coexists with relatively small ones (for example the fulling machineries), which are still satisfying the needs of current production. The objective the pilot is to maximize the exploitation of the current production infrastructure balancing the lot dimensions of the two categories of machines, to reduce the costs, to increase the efficiency of the department	The main parameters which affect the optimal production management of finishing are the lot dimension per machine, the number of stops and the non-exploited time in idle state (but heat and energy consuming). The speed is related with the number of stops for product lot preparation (for ex for dryers) and for manual quality control (for example for fulling machines, where no sensors are available).	The pilot is expected to find the best balancing of the whole process optimization in relation with the different lot dimensions. Due to the high heat, energy and water needs the optimization of the process is expected to provide a reduction of gas, electricity and water need and to enhance the overall sustainability of the manufacturing process	**Cost**	4
			Efficiency	5
			Quality	5
			Flexibility	3
			Innovation	2
			Sustainability	5

[9] These six categories of effect proposed, comes from the EU Project COMVANTAGE*, where the aspect at the business process level in which an improvement is expected to occur are:

- **Cost**: ICT capabilities can contribute to cost reduction in various ways: Automation and standardization of tasks, qualify workers faster and better, inventory and stock management improve and integrating the suppliers into its customer´s ICT.
- **Efficiency**: ICT capabilities can contribute to improve efficiency in various ways: Improve availability and efficiency of machines, enabling easy access of maintenance employees to relevant information, facilitating identification and analysis of problems, shortening the response time to malfunctions, optimization of the machine´s activity scheduling and automating decisions regarding maintenance and production activities.
- **Quality**: ICT capabilities can contribute to improve quality in various ways: Supporting the creation of the characteristics of the product or service, understanding the requirements that the product or service should fulfil, increase the feet to the specification of the product or service (decrease errors), improve the communication of the involved parties in the creation and delivery of the product or service, making information about the customer´s order available from initiation to completion, facilitating transparency and early identification of deviation from desire outcome, adapting to the changing need of customer's and the constrains of suppliers, facilitating better understanding of customer´s needs and generating inside into de customer´s tacit as well as explicit needs and requirements.
- **Flexibility**: ICT capabilities can contribute to improve flexibility by product and service customization to adapt to market changes and customers preferred options at designed stage.
- **Innovation**: ICT capabilities can contribute to improve flexibility by product and service customization to adapt to market changes and customers preferred options at designed stage.
- **Sustainability:** ICT capabilities can contribute to improve sustainability by reducing carbon footprint in three ways: Reduced paper usage, reduction of energy consumption and reduce fuel consumption in distribution.

3.3.2 KPI's

Business KPI for the Piacenza pilot derive from the main KPI of the total cost, already described in part 3.3.1.3.

3.3.2.1 Description of KPI's

The following table describes the business KPIs

Table 3.8 Business KPIs for Weaving Process

BUSINESS Indicators	DESCRIPTION	Unit
Average warp length	This parameter indicates the average length of the warp of the fabrics produced by the looms. Since the timing to prepare each warp as well as the time to upload it in the loom is almost fixed the optimisation of the warp length is a key indicator of weaving department optimisation. Production management must also take into proper account the chainability of fabrics, which indicates if different designs do share the same warp and therefore can be "chained" together.	Average length of the warp in meters (in total and divided per season and category, e.g. sample and regular production)
Production of the department in meters	Total meters produced internally by Piacenza weaving department	Total production of fabrics in meters (in total and divided per season and category, e.g. sample and regular production)
Production of the department in meters	Total meters produced internally by Piacenza weaving department	Total production of fabrics in meters (in total and divided per season and category, e.g. sample and regular production)
Level of weaving department exploitation vs total production	% of exploitation of the available looms in relation with the total production	In percentage per year
Delivery time	Average delivery time of the woven fabric to the finishing department	Time in days
New order management: planning update and	Improved planning of the incoming orders over the production process in order to	Time in days

BUSINESS Indicators	DESCRIPTION	Unit
release of expected delivery indication.	match the deadlines and the energy savings goals.	

Table 3.9 Business KPIs for Finishing Process

BUSINESS Indicators	DESCRIPTION	Unit
Average lot dimension	This parameter indicates the average length of the lot of the fabrics produced by the finishing department.	Average length of the lot in meters)
Production of the department in meters	Total meters produced internally by Piacenza weaving department	Total production of fabrics in meters (in total and divided per production step, season and category, e.g. sample and regular production)
Delivery time	Average delivery time from the receipt of the woven fabric to the delivery of the finished fabric	Time in days
New order management: planning update and release of expected delivery indication.	Improved planning of the incoming orders over the production process in order to match the deadlines and the energy savings goals	Time in days

According to the weaving and finishing KPI it is possible to determine also the whole plant KPIs, as stated into the project Description of Work.

Table 3.10 Business KPIs for The Whole Plant

BUSINESS Indicators	DESCRIPTION	Unit
Improved data collection	machineries integrated into data collection process	%
Energy efficiency	energy wasted for production not efficient scheduling	%
Environmental efficiency	CO2 emissions for not efficient production management, direct (machineries) and services (depuration, illumination, climatisation)	%

3.3.2.2 Baseline and target values for KPI's

Table 3.11 Business KPIs for Weaving Process: Baseline and Target Values

BUSINESS Indicators	Unit	Current Value	Expected value
Average warp length	Average length of the warp in meters (in total and divided per season and category, e.g. sample and regular production)	183m	+30%
Production of the department in meters	Total production of fabrics in meters (in total and divided per season and category, e.g. sample and regular production)	361.000 m (38% of the total production)	+25%
Level of weaving department exploitation vs total production	In percentage per year.	31% absolute technical exploitation (63% if we consider only the variables related with the weaving excluding the external ones)	+35%
Delivery time	Time in days	7 weeks	-20%
New order management: planning update and release of expected delivery indication.	Time in days	3 days	-20%

Table 3.12 Business KPIs for Finishing Process: Baseline and Target Values

BUSINESS Indicators	Unit	Current Value	Expected value
Average lot dimension	Average length of the lot in meters)	150 m	+30%
Production of the department in meters	Total production of fabrics in meters (in total and divided per production step, season	829.000 meters	+10%

BUSINESS Indicators	Unit	Current Value	Expected value
	and category, e.g. sample and regular production)		
Delivery time	Time in days	3 weeks	-20%
New order management: planning update and release of expected delivery indication.	Time in days	2 days	-20%

Table 3.13 Business KPIs for The Whole Plant: Baseline and Target Values

BUSINESS Indicators	Current Value	Expected value
Improved data collection	< 60%	+33% to reach >80% coverage
Energy efficiency	> 30%	-65% to less than 10%
Environmental efficiency	> 30%	-65% to less than 10%

3.3.3 Initial Datasets

At present, the ERP management software of the warping department provides the necessary data to produce the warp chain through the department array. This array contains the colour notes (warp notes) to define the sequence of colours and yarns needed to compose the warp of the chain itself. This data is integrated with the management software of the machinery (warp) through private protocol defined by the constructor, placed on the computer of the machinery itself.

The initial identified datasets include:

- Data relevant to the set of machines that are involved in all process steps
- Data relevant to the raw materials
- Data relevant to the set of orders
- Data relevant to energy consumption

Moreover, a focus on the Finishing Department is needed. The finishing process groups together the production steps applied to the fabric after the looming. The goal of this department is to improve the aspect, the touch and the features of the final product, making a stable fabric for the next production steps. These operations give to the different fabrics the quality and structural characteristics in order to ensure an excellent behaviour during the tailoring. These finishing steps, which can last up to several weeks for the completion, are made on different machineries.

The productive reality of this department is rather problematic, because it includes a set of extremely heterogeneous processes needed to reach the final product (fabric) that completely satisfies the qualitative standards demanded by fashion companies. Finishing processes and procedures for the management of criticalities are not organized in a structural way. They come up from the personal experience of the department operators (mainly head departments), whom transfer then manually according to the circumstances, to the commercial department of the company. Above all, there are no objective elements on which we could base an idea of production planning with time and resource optimization, using at best the knowledge that a system can supply, according to situations already faced.

3.4 Automotive Sector: Pilot Case by CONT

3.4.1 Reference Scenario

Continental is producing high electronic products, designed by the group of development within different worldwide locations. Products are customized our final customer from design phase for, automotive OEM's. Although these products (e.g. airbag control units, chaises controllers, hand brake controllers etc.) have a high complexity degree, their routings can be described (in brief) as follows.

- **SMT (Surface Mount Technology) lines.** High automated lines where electronic components are placed on the PCB boards.
- **PCBA (Printed Circuit Board Area).** PCB area, where the electronic built in SMT will be separated in smaller parts (PCB's) and tested electrically (In Circuit Test). Additional processes can also take place in this area like Press Fit, Handling, Flashing of Microcontrollers and Temperature functional tests.
- **FA (Final Assembly) and Test Area.** This is the step of production where the electronic is connected to the mechanical part and finally tested and labelled. The processes in this area are in the area of connecting the mechanical parts: Screwing, Press Fit, Gluing, Riveting, Snap In. The testing area consists of tests line Functional test of the product, Automatic Optical Inspection, Force monitoring for the snap in, air leakage test.
- **Packaging and delivery operation.** Within this step of manufacturing we are packing the products in customer specific boxes and link all the information needed by customer to the unique number of each box.

To maximize life-time of equipment's involved in production processes (Process equipment but also Test equipment), Continental maintenance & repair departments perform different maintenance techniques. Also, workers from the shop floor play an important role through the information provided about equipment's' behaviour in operations. In this regard, **valuable information is gathered and interpreted in order to detect early possible failures or defects. Inspection, maintenance and repair activities are performed daily** to annually, in conjunction with the technical prescriptions and machine age. Mainly process characteristics that are tracked are:

a) Process parameters e.g. torque, pressing forces,
b) measured values of the electronic components,
c) product reaction in different temperatures,
d) wearing of the tools during production phase (v) deviations from accuracies machining / processing.

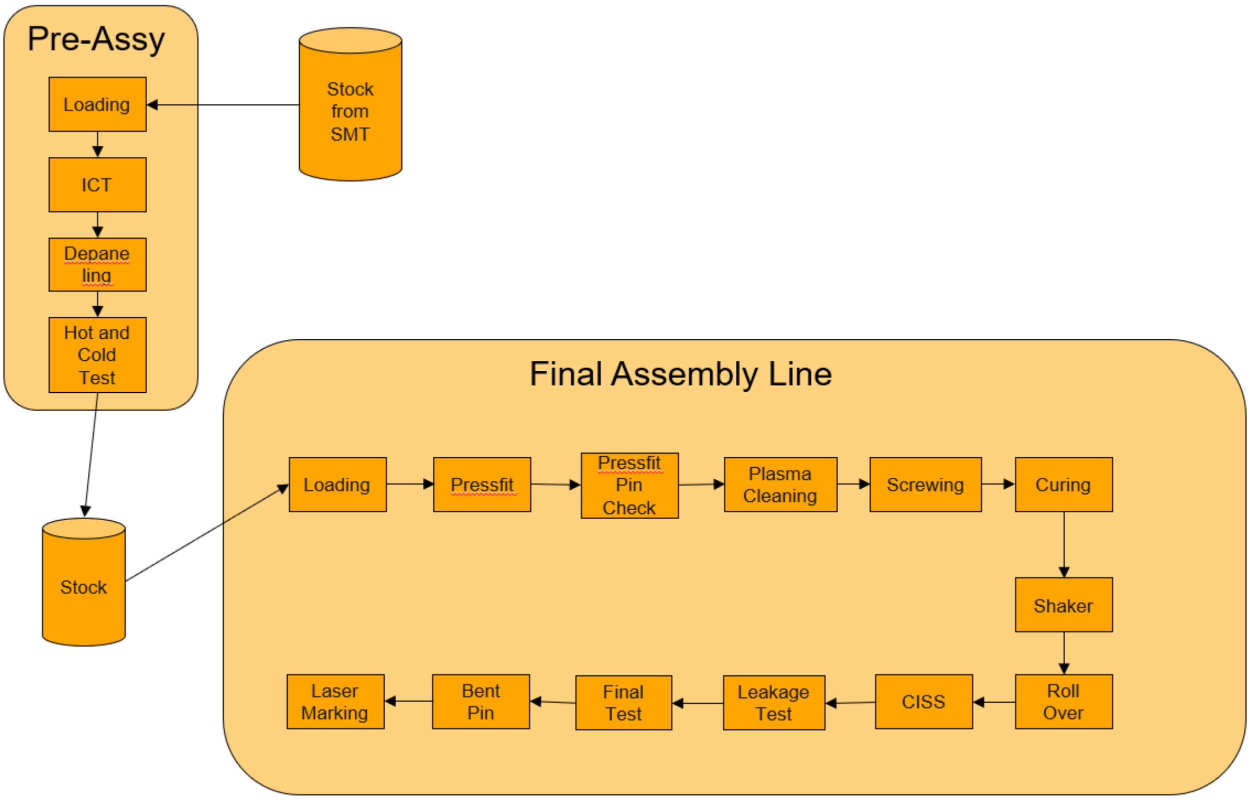
3.4.1.1 Context: The business case and As-Is process flow

FACTLOG project will support the improvement of monitoring the Pre - Assembly lines and is Final Assembly lines and move from only parameter monitoring to automatic reporting, automatic preventive maintenance.

Description workflow for Pre-Assembly and FA and Test Area

For the FACTLOG project the introduced lines are a Pre- Assembly line and a Final Assembly line with the process presented in the diagram and further it will be implemented on the others PRE and Final Assembly Line.

Below the Pre-Assy and Final Assembly Diagram is presented:



Pre-Assembly

Loading: On this station CONT gets the multi panel from SMT Stock and create in WIP (Work in Progress) module each single sub unit.

ICT Process: Even if we load into the ICT station the entire multi panel the testing it is done on each single unit.

Mark the units as PASS/FAIL on this station in our WIP module.

On this station each single unit it is tested, and all measured values are stored in EvaPROD

Id	Timestamp	SerialNumber	Station	StationType	StationNum	Material	TestDescription	TestValue	TestResult	USL	LSL	Format
46049	7/2/2020 9:55:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	ICT	Preassy	1	A2C58073215	5_l6174%j1-4A-JUM_1	4.986564	Pass	16	0	e13
46050	7/2/2020 9:55:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	ICT	Preassy	1	A2C58073215	6_l6174%j2-3A-JUM_1	5.133933	Pass	16	0	e13
46051	7/2/2020 9:55:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	ICT	Preassy	1	A2C58073215	7_l7231%j1-2A-JUM_1	3.373	Pass	16	0	e13
46052	7/2/2020 9:55:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	ICT	Preassy	1	A2C58073215	8_l7241%j1-2A-JUM_1	3.453361	Pass	16	0	e13
46053	7/2/2020 9:55:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	ICT	Preassy	1	A2C58073215	9_l7320%j1-2A-JUM_1	4.444641	Pass	16	0	e13
46054	7/2/2020 9:55:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	ICT	Preassy	1	A2C58073215	10_l7361%j1-2A-JUM_1	3.857993	Pass	16	0	e13
46055	7/2/2020 9:55:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	ICT	Preassy	1	A2C58073215	11_r5101A-JUM_1	3.434775	Pass	16	0	e13
46056	7/2/2020 9:55:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	ICT	Preassy	1	A2C58073215	12_r5102A-JUM_1	3.349641	Pass	16	0	e13
46057	7/2/2020 9:55:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	ICT	Preassy	1	A2C58073215	13_r5103A-JUM_1	3.470314	Pass	16	0	e13
46058	7/2/2020 9:55:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	ICT	Preassy	1	A2C58073215	14_r5104A-JUM_1	3.339902	Pass	16	0	e13
46059	7/2/2020 9:55:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	ICT	Preassy	1	A2C58073215	15_r6311A-JUM_1	3.546108	Pass	16	0	e13
46060	7/2/2020 9:55:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	ICT	Preassy	1	A2C58073215	16_r7242A-JUM_1	13.46284	Pass	16	0	e13
46061	7/2/2020 9:55:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	ICT	Preassy	1	A2C58073215	17_xm1120%j1-2A-JUM_1	3.47215	Pass	16	0	e13
46062	7/2/2020 9:55:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	ICT	Preassy	1	A2C58073215	18_shorts00000000001%shorts	0	Pass	0	0	e13
46063	7/2/2020 9:55:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	ICT	Preassy	1	A2C58073215	19_r7255A-RES_1	7477.857	Pass	7800	7200	e13
46064	7/2/2020 9:55:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	ICT	Preassy	1	A2C58073215	20_r8161A-RES_1	7487.691	Pass	7800	7200	e13
46065	7/2/2020 9:55:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	ICT	Preassy	1	A2C58073215	21_r8162A-RES_1	7480.86	Pass	7800	7200	e13
46066	7/2/2020 9:55:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	ICT	Preassy	1	A2C58073215	22_r8184A-RES_1	7442.422	Pass	7800	7200	e13
46067	7/2/2020 9:55:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	ICT	Preassy	1	A2C58073215	23_r8185A-RES_1	7488.922	Pass	7800	7200	e13
46068	7/2/2020 9:55:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	ICT	Preassy	1	A2C58073215	24_r5187A-RES_1	47.09375	Pass	48.88	45.12	e13

Depaneling: This is the process where CONT makes the physical split of the sub unit from multi panel.

Mark the units as PASS/FAIL on this station in our WIP module.

Store process values in EvaPROD module:

Make a separation between PASS unit and FAIL/SCRAP units.

Hot and Cold Test: On this station the units are tested on high temperature and on low temperature.

Mark the units as PASS/FAIL on this station in our WIP module.

On this station each single unit it is tested, and all measured values are stored in EvaPROD

Id	Timestamp	SerialNumber	Station	StationType	StationNum	Material	TestDescription	TestValue	TestResult	USL	LSL	Format
47049	7/2/2020 9:57:47 PM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CTT-HT	Preassy	4	A2C58073215	1 - 9995 DTP_VERSION	1	Pass	1	1	R8.0
47050	7/2/2020 9:57:47 PM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CTT-HT	Preassy	4	A2C58073215	2 - 0996 DTP_Check_and_Read	1	Pass	1	1	R9.9
47051	7/2/2020 9:57:47 PM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CTT-HT	Preassy	4	A2C58073215	3 - 0997 DTP_Read_Variables	1	Pass	1	1	R9.9
47052	7/2/2020 9:57:47 PM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CTT-HT	Preassy	4	A2C58073215	4 - 0010_0 Check_Read_ETS_Lim	0	Pass	0	0	R9.9
47053	7/2/2020 9:57:47 PM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CTT-HT	Preassy	4	A2C58073215	5 - 0001_1 Uc3_HW_Configurati	1	Pass	1	1	R9.9
47054	7/2/2020 9:57:47 PM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CTT-HT	Preassy	4	A2C58073215	6 - 0001_2 Read_SW_Version_re	1	Pass	1	1	R9.9
47055	7/2/2020 9:57:47 PM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CTT-HT	Preassy	4	A2C58073215	7 - 0007_1 config(01)_Uc3_requ	1	Pass	1	1	R9.9
47056	7/2/2020 9:57:47 PM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CTT-HT	Preassy	4	A2C58073215	8 - 0007_2 config(01)_Uc3_recei	1	Pass	1	1	R9.9
47057	7/2/2020 9:57:47 PM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CTT-HT	Preassy	4	A2C58073215	14 - 0005_1 init(98)_Uc3_HW_re	1	Pass	1	1	R9.9
47058	7/2/2020 9:57:47 PM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CTT-HT	Preassy	4	A2C58073215	15 - 0005_2 ini(98)_Uc3_HW_rec	1	Pass	1	1	R9.9
47059	7/2/2020 9:57:47 PM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CTT-HT	Preassy	4	A2C58073215	16 - 0006_1 Uc3_Activate_Modu	1	Pass	1	1	R9.9
47060	7/2/2020 9:57:47 PM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CTT-HT	Preassy	4	A2C58073215	17 - 0006_2 Uc3_Activate_Modu	1	Pass	1	1	R9.9
47061	7/2/2020 9:57:47 PM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CTT-HT	Preassy	4	A2C58073215	18 - 0007_1 config(01)_Uc3_requ	1	Pass	1	1	R9.9
47062	7/2/2020 9:57:47 PM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CTT-HT	Preassy	4	A2C58073215	19 - 0007_2 config(01)_Uc3_rece	1	Pass	1	1	R9.9
47063	7/2/2020 9:57:47 PM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CTT-HT	Preassy	4	A2C58073215	20 - 1001_12 init(98)_Uc3_HW_r	1	Pass	1	1	R9.9
47064	7/2/2020 9:57:47 PM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CTT-HT	Preassy	4	A2C58073215	21 - 1001_13 ini(98)_Uc3_HW_re	1	Pass	1	1	R9.9
47065	7/2/2020 9:57:47 PM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CTT-HT	Preassy	4	A2C58073215	22 - 1001_14 Adjust_Offset_par	1	Pass	1	1	R9.9
47066	7/2/2020 9:57:47 PM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CTT-HT	Preassy	4	A2C58073215	23 - 1001_15 Adjust_Offset_Par	1	Pass	1	1	R9.9
47067	7/2/2020 9:57:47 PM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CTT-HT	Preassy	4	A2C58073215	24 - 1001_14 Download_Flashin	1	Pass	1	1	R8.0
47068	7/2/2020 9:57:47 PM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CTT-HT	Preassy	4	A2C58073215	25 - 1001_15 Download_Flashin	1	Pass	1	1	R8.0

All PASS units are moved to the stock to be ready for next level of assembly.

All produced units are from a specific material/product number until this stock level.

On the next level of assembly will become a different product based on the customer requests.

Loading: On this station we get the unit from stock level and create it in WIP into an order for the needed material.

Mark the units as PASS/FAIL on this station in our WIP module.

Pressfit: On this station we assemble the PCB into a housing.

After this station the datamatrix from PCB is not visible/readable anymore and we are making a so-called Unit Change from PCB to Housing unique serial number. This is done to assure the traceability and process control of our products.

Mark the units as PASS/FAIL on this station in our WIP module.

On this station each single unit it is tested, and we store all measured values in EvaPROD

Id	Timestamp	SerialNumber	Station	StationType	StationNum	Material	TestDescription	TestValue	TestResult	USL	LSL	Format
47853	7/3/2020 7:57:35 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT	Final Assembly	6	A2C15768304	Carrier no	49	Pass	9999	0	R6.2
47854	7/3/2020 7:57:35 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT	Final Assembly	6	A2C15768304	Force value	4.132	Pass	4.95	3.3	R6.2
47855	7/3/2020 7:57:35 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT	Final Assembly	6	A2C15768304	Distance value	55.243	Pass	56.14	54.33	R6.3
50705	7/3/2020 7:57:57 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	PRSFIT	Final Assembly	6	A2C15768304	Carrier no	18	Pass	9999	0	R6.2
50706	7/3/2020 7:57:57 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	PRSFIT	Final Assembly	6	A2C15768304	Force value	4.132	Pass	4.95	3.3	R6.2
50707	7/3/2020 7:57:57 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	PRSFIT	Final Assembly	6	A2C15768304	Distance value	55.23	Pass	56.14	54.33	R6.3
54226	7/3/2020 7:51:37 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730704*=	PRSFIT	Final Assembly	6	A2C15768304	Carrier no	10	Pass	9999	0	R6.2
54227	7/3/2020 7:51:37 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730704*=	PRSFIT	Final Assembly	6	A2C15768304	Force value	4.132	Pass	4.95	3.3	R6.2
54228	7/3/2020 7:51:37 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730704*=	PRSFIT	Final Assembly	6	A2C15768304	Distance value	55.209	Pass	56.14	54.33	R6.3
57078	7/3/2020 7:59:12 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720703*=	PRSFIT	Final Assembly	6	A2C15768304	Carrier no	37	Pass	9999	0	R6.2
57079	7/3/2020 7:59:12 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720703*=	PRSFIT	Final Assembly	6	A2C15768304	Force value	4.132	Pass	4.95	3.3	R6.2
57080	7/3/2020 7:59:12 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720703*=	PRSFIT	Final Assembly	6	A2C15768304	Distance value	55.201	Pass	56.14	54.33	R6.3
59930	7/3/2020 7:59:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730706*=	PRSFIT	Final Assembly	6	A2C15768304	Carrier no	39	Pass	9999	0	R6.2
59931	7/3/2020 7:59:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730706*=	PRSFIT	Final Assembly	6	A2C15768304	Force value	4.132	Pass	4.95	3.3	R6.2
59932	7/3/2020 7:59:34 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730706*=	PRSFIT	Final Assembly	6	A2C15768304	Distance value	55.224	Pass	56.14	54.33	R6.3
62782	7/3/2020 7:59:55 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720705*=	PRSFIT	Final Assembly	6	A2C15768304	Carrier no	13	Pass	9999	0	R6.2
62783	7/3/2020 7:59:55 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720705*=	PRSFIT	Final Assembly	6	A2C15768304	Force value	4.132	Pass	4.95	3.3	R6.2
62784	7/3/2020 7:59:55 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720705*=	PRSFIT	Final Assembly	6	A2C15768304	Distance value	55.295	Pass	56.14	54.33	R6.3
65634	7/3/2020 7:58:42 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720707*=	PRSFIT	Final Assembly	6	A2C15768304	Carrier no	11	Pass	9999	0	R6.2
65635	7/3/2020 7:58:42 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720707*=	PRSFIT	Final Assembly	6	A2C15768304	Force value	4.132	Pass	4.95	3.3	R6.2
65636	7/3/2020 7:58:42 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720707*=	PRSFIT	Final Assembly	6	A2C15768304	Distance value	55.253	Pass	56.14	54.33	R6.3
68486	7/3/2020 8:01:05 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720709*=	PRSFIT	Final Assembly	6	A2C15768304	Carrier no	2	Pass	9999	0	R6.2
68487	7/3/2020 8:01:05 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720709*=	PRSFIT	Final Assembly	6	A2C15768304	Force value	4.132	Pass	4.95	3.3	R6.2

Pressfit Pin Check: Because on the previous station the PCB was assembled into a housing and the PCB is fixed into some pins, on this station we check if everything is ok with each and every pin. We need to assure that after the pressfit all pins are in the correct shape.

Mark the units as PASS/FAIL on this station in our WIP module.

On this station each single unit it is tested, and we store all measured values in EvaPROD

Id	Timestamp	SerialNumber	Station	StationType	StationNum	Material	TestDescription	TestValue	TestResult	USL	LSL	Format
47866	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Carrier no	49	Pass	9999	0	R6.2
47867	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 1 value	1.76	Pass	3	1.45	R6.2
47868	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 2 value	1.78	Pass	3	1.45	R6.2
47869	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 3 value	1.77	Pass	3	1.45	R6.2
47870	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 4 value	1.79	Pass	3	1.45	R6.2
47871	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 5 value	1.46	Pass	3	1	R6.2
47872	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 6 value	1.46	Pass	3	1	R6.2
47873	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 7 value	1.47	Pass	3	1	R6.2
47874	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 8 value	99	Pass	999	-999	R6.2
47875	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 9 value	1.42	Pass	3	1	R6.2
47876	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 10 value	1.43	Pass	3	1	R6.2
47877	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 11 value	99	Pass	999	-999	R6.2
47878	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 12 value	1.45	Pass	3	1	R6.2
47879	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 13 value	1.46	Pass	3	1	R6.2
47880	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 14 value	99	Pass	999	-999	R6.2
47881	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 15 value	1.45	Pass	3	1	R6.2
47882	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 16 value	99	Pass	999	-999	R6.2
47883	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 17 value	1.46	Pass	3	1	R6.2
47884	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 18 value	1.47	Pass	3	1	R6.2
47885	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 19 value	1.49	Pass	3	1	R6.2
47886	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 20 value	99	Pass	999	-999	R6.2
47887	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 21 value	99	Pass	999	-999	R6.2
47888	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 22 value	1.5	Pass	3	1	R6.2
47889	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 23 value	1.5	Pass	3	1	R6.2
47890	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 24 value	1.5	Pass	3	1	R6.2
47891	7/3/2020 7:57:52 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PRSFIT_PINCHECK	Final Assembly	7	A2C15768304	Pin 25 value	1.51	Pass	3	1	R6.2

Plasma Cleaning: On this process glue is dispensed on the product and a base plate is assmbled.

Mark the units as PASS/FAIL on this station in our WIP module.

On this station each single unit it is tested, and we store all measured values in EvaPROD

Id	Timestamp	SerialNumber	Station	StationType	StationNum	Material	TestDescription	TestValue	TestResult	USL	LSL	Format
48892	7/3/2020 7:58:39 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PLASMACLEAN	Final Assembly	8	A2C15768304	RPM value	2934	Pass	99999	-999	R6.2
48893	7/3/2020 7:58:39 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PLASMACLEAN	Final Assembly	8	A2C15768304	Carrier no	49	Pass	9999	0	R6.2
48894	7/3/2020 7:58:39 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PLASMACLEAN	Final Assembly	8	A2C15768304	Tension value	291	Pass	99999	-999	R6.2
48895	7/3/2020 7:58:39 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PLASMACLEAN	Final Assembly	8	A2C15768304	Intensity value	15.5	Pass	99999	-999	R6.2
48896	7/3/2020 7:58:39 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PLASMACLEAN	Final Assembly	8	A2C15768304	Power value	4510.5	Pass	99999	-999	R6.2
48897	7/3/2020 7:58:39 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	PLASMACLEAN	Final Assembly	8	A2C15768304	Air pressure value	28	Pass	99999	-999	R6.2
51744	7/3/2020 7:59:03 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	PLASMACLEAN	Final Assembly	8	A2C15768304	RPM value	2935	Pass	99999	-999	R6.2
51745	7/3/2020 7:59:03 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	PLASMACLEAN	Final Assembly	8	A2C15768304	Carrier no	18	Pass	9999	0	R6.2
51746	7/3/2020 7:59:03 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	PLASMACLEAN	Final Assembly	8	A2C15768304	Tension value	291	Pass	99999	-999	R6.2
51747	7/3/2020 7:59:03 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	PLASMACLEAN	Final Assembly	8	A2C15768304	Intensity value	15.5	Pass	99999	-999	R6.2
51748	7/3/2020 7:59:03 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	PLASMACLEAN	Final Assembly	8	A2C15768304	Power value	4510.5	Pass	99999	-999	R6.2
51749	7/3/2020 7:59:03 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	PLASMACLEAN	Final Assembly	8	A2C15768304	Air pressure value	27	Pass	99999	-999	R6.2
55265	7/3/2020 7:52:37 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730704*=	PLASMACLEAN	Final Assembly	8	A2C15768304	RPM value	2936	Pass	99999	-999	R6.2
55266	7/3/2020 7:52:37 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730704*=	PLASMACLEAN	Final Assembly	8	A2C15768304	Carrier no	10	Pass	9999	0	R6.2
55267	7/3/2020 7:52:37 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730704*=	PLASMACLEAN	Final Assembly	8	A2C15768304	Tension value	292	Pass	99999	-999	R6.2
55268	7/3/2020 7:52:37 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730704*=	PLASMACLEAN	Final Assembly	8	A2C15768304	Intensity value	15.5	Pass	99999	-999	R6.2
55269	7/3/2020 7:52:37 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730704*=	PLASMACLEAN	Final Assembly	8	A2C15768304	Power value	4526	Pass	99999	-999	R6.2
55270	7/3/2020 7:52:37 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730704*=	PLASMACLEAN	Final Assembly	8	A2C15768304	Air pressure value	29	Pass	99999	-999	R6.2
58117	7/3/2020 8:00:16 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720703*=	PLASMACLEAN	Final Assembly	8	A2C15768304	RPM value	2952	Pass	99999	-999	R6.2
58118	7/3/2020 8:00:16 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720703*=	PLASMACLEAN	Final Assembly	8	A2C15768304	Carrier no	37	Pass	9999	0	R6.2
58119	7/3/2020 8:00:16 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720703*=	PLASMACLEAN	Final Assembly	8	A2C15768304	Tension value	292	Pass	99999	-999	R6.2
58120	7/3/2020 8:00:16 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720703*=	PLASMACLEAN	Final Assembly	8	A2C15768304	Intensity value	15.5	Pass	99999	-999	R6.2
58121	7/3/2020 8:00:16 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720703*=	PLASMACLEAN	Final Assembly	8	A2C15768304	Power value	4526	Pass	99999	-999	R6.2

Screwing: On this station we are screwing the base plate together with the housing and PCB.

Mark the units as PASS/FAIL on this station in our WIP module.

On this station each single unit it is tested, and we store all measured values in EvaPROD

Id	Timestamp	SerialNumber	Station	StationType	StationNum	Material	TestDescription	TestValue	TestResult	USL	LSL	Format
48449	7/3/2020 8:00:18 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SCREWING	Final Assembly	10	A2C15768304	Torque 1 value	2	Pass	2.1	1.9	R6.2
48450	7/3/2020 8:00:18 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SCREWING	Final Assembly	10	A2C15768304	Carrier no	49	Pass	9999	0	R6.2
48451	7/3/2020 8:00:18 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SCREWING	Final Assembly	10	A2C15768304	Torque 2 value	2	Pass	2.1	1.9	R6.2
48452	7/3/2020 8:00:18 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SCREWING	Final Assembly	10	A2C15768304	Torque 3 value	2.01	Pass	2.1	1.9	R6.2
48453	7/3/2020 8:00:18 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SCREWING	Final Assembly	10	A2C15768304	Torque 4 value	2.01	Pass	2.1	1.9	R6.2
48454	7/3/2020 8:00:18 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SCREWING	Final Assembly	10	A2C15768304	Height 1 value	26.74	Pass	28	26	R6.2
48455	7/3/2020 8:00:18 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SCREWING	Final Assembly	10	A2C15768304	Height 2 value	26.52	Pass	28	26	R6.2
48456	7/3/2020 8:00:18 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SCREWING	Final Assembly	10	A2C15768304	Height 3 value	26.73	Pass	28	26	R6.2
48457	7/3/2020 8:00:18 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SCREWING	Final Assembly	10	A2C15768304	Height 4 value	26.71	Pass	28	26	R6.2
48458	7/3/2020 8:00:18 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SCREWING	Final Assembly	10	A2C15768304	Angle 1 value	14	Pass	180	0	R6.2
48459	7/3/2020 8:00:18 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SCREWING	Final Assembly	10	A2C15768304	Angle 2 value	9	Pass	180	0	R6.2
48460	7/3/2020 8:00:18 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SCREWING	Final Assembly	10	A2C15768304	Angle 3 value	6	Pass	180	0	R6.2
48461	7/3/2020 8:00:18 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SCREWING	Final Assembly	10	A2C15768304	Angle 4 value	11	Pass	180	0	R6.2
51301	7/3/2020 8:00:43 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	SCREWING	Final Assembly	10	A2C15768304	Torque 1 value	2	Pass	2.1	1.9	R6.2
51302	7/3/2020 8:00:43 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	SCREWING	Final Assembly	10	A2C15768304	Carrier no	18	Pass	9999	0	R6.2
51303	7/3/2020 8:00:43 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	SCREWING	Final Assembly	10	A2C15768304	Torque 2 value	2	Pass	2.1	1.9	R6.2
51304	7/3/2020 8:00:43 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	SCREWING	Final Assembly	10	A2C15768304	Torque 3 value	2.01	Pass	2.1	1.9	R6.2
51305	7/3/2020 8:00:43 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	SCREWING	Final Assembly	10	A2C15768304	Torque 4 value	2	Pass	2.1	1.9	R6.2
51306	7/3/2020 8:00:43 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	SCREWING	Final Assembly	10	A2C15768304	Height 1 value	26.77	Pass	28	26	R6.2
51307	7/3/2020 8:00:43 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	SCREWING	Final Assembly	10	A2C15768304	Height 2 value	26.53	Pass	28	26	R6.2
51308	7/3/2020 8:00:43 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	SCREWING	Final Assembly	10	A2C15768304	Height 3 value	26.69	Pass	28	26	R6.2
51309	7/3/2020 8:00:43 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	SCREWING	Final Assembly	10	A2C15768304	Height 4 value	26.66	Pass	28	26	R6.2
51310	7/3/2020 8:00:43 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	SCREWING	Final Assembly	10	A2C15768304	Angle 1 value	14	Pass	180	0	R6.2
51311	7/3/2020 8:00:43 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	SCREWING	Final Assembly	10	A2C15768304	Angle 2 value	11	Pass	180	0	R6.2
51312	7/3/2020 8:00:43 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	SCREWING	Final Assembly	10	A2C15768304	Angle 3 value	11	Pass	180	0	R6.2
51313	7/3/2020 8:00:43 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015720701*=	SCREWING	Final Assembly	10	A2C15768304	Angle 4 value	12	Pass	180	0	R6.2
54822	7/3/2020 7:53:56 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730704*=	SCREWING	Final Assembly	10	A2C15768304	Torque 1 value	1.99	Pass	2.1	1.9	R6.2
54823	7/3/2020 7:53:56 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730704*=	SCREWING	Final Assembly	10	A2C15768304	Carrier no	10	Pass	9999	0	R6.2

Curing: On this station we just store the time stamp in EvaPROD module in order to make a time difference on a further process.

Mark the units as PASS (no FAIL possible on this station) on this station in our WIP module.

Shaker: This is a test station which is making a shaking test with a specific G-Force.

Mark the units as PASS/FAIL on this station in our WIP module.

On this station each single unit it is tested, and we store all measured values in EvaPROD

Id	Timestamp	SerialNumber	Station	StationType	StationNum	Material	TestDescription	TestValue	TestResult	USL	LSL	Format
48009	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	4 - 1001_1 Uc3_HW_Configurati	1	Pass	1	1	R9.9
48010	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	5 - 1001_2 Read_SW_Version_re	1	Pass	1	1	R9.9
48011	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	6 - 1001_3 Read_SW_Version_re	1	Pass	1	1	R9.9
48012	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	7 - 1001_4 config(01)_Uc3_requ	1	Pass	1	1	R9.9
48013	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	8 - 1001_5 config(01)_Uc3_recei	1	Pass	1	1	R9.9
48014	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	14 - 1001_6 init(98)_Uc3_HW_re	1	Pass	1	1	R9.9
48015	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	15 - 1001_7 ini(98)_Uc3_HW_rec	1	Pass	1	1	R9.9
48016	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	16 - 1001_8 Uc3_Activate_Modu	1	Pass	1	1	R9.9
48017	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	17 - 1001_9 Uc3_Activate_Modu	1	Pass	1	1	R9.9
48018	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	18 - 1001_10 config(01)_Uc3_rec	1	Pass	1	1	R9.9
48019	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	19 - 1001_11 config(01)_Uc3_rec	1	Pass	1	1	R9.9
48020	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	20 - 1001_12 init(98)_Uc3_HW_r	1	Pass	1	1	R9.9
48021	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	21 - 1001_13 ini(98)_Uc3_HW_re	1	Pass	1	1	R9.9
48022	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	22 - 1001_14 Adjust_Offset_para	1	Pass	1	1	R9.9
48023	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	23 - 1001_15 Adjust_Offset_Para	1	Pass	1	1	R9.9
48024	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	24 - 1001_15 Start_embedded_T	1	Pass	1	1	R8.0
48025	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	25 - 1001_16 Start_embedded_T	1	Pass	1	1	R8.0
48026	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	26 - 1001_18 init(98)_Uc3_HW_r	1	Pass	1	1	R9.9
48027	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	27 - 1001_19 ini(98)_Uc3_HW_re	1	Pass	1	1	R9.9
48028	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	28 - 1001_20 init(98)_Uc3_HW_r	1	Pass	1	1	R9.9
48029	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	29 - 1001_21 ini(98)_Uc3_HW_re	1	Pass	1	1	R9.9
48030	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	30 - 1001_22 config(01)_Uc3_rec	1	Pass	1	1	R9.9
48031	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	31 - 1001_23 config(01)_Uc3_rec	1	Pass	1	1	R9.9
48032	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	32 - 1001_24 Read_Flashing_Toc	1	Pass	1	1	R9.9

Roll Over: This is a test station which is making a roll over test of the products.

Mark the units as PASS/FAIL on this station in our WIP module.

On this station each single unit it is tested, and we store all measured values in EvaPROD

Id	Timestamp	SerialNumber	Station	StationType	StationNum	Material	TestDescription	TestValue	TestResult	USL	LSL	Format
48009	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	4 - 1001_1 Uc3_HW_Configurati	1	Pass	1	1	R9.9
48010	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	5 - 1001_2 Read_SW_Version_re	1	Pass	1	1	R9.9
48011	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	6 - 1001_3 Read_SW_Version_re	1	Pass	1	1	R9.9
48012	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	7 - 1001_4 config(01)_Uc3_requ	1	Pass	1	1	R9.9
48013	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	8 - 1001_5 config(01)_Uc3_recei	1	Pass	1	1	R9.9
48014	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	14 - 1001_6 init(98)_Uc3_HW_re	1	Pass	1	1	R9.9
48015	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	15 - 1001_7 ini(98)_Uc3_HW_rec	1	Pass	1	1	R9.9
48016	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	16 - 1001_8 Uc3_Activate_Modu	1	Pass	1	1	R9.9
48017	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	17 - 1001_9 Uc3_Activate_Modu	1	Pass	1	1	R9.9
48018	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	18 - 1001_10 config(01)_Uc3_rec	1	Pass	1	1	R9.9
48019	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	19 - 1001_11 config(01)_Uc3_rec	1	Pass	1	1	R9.9
48020	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	20 - 1001_12 init(98)_Uc3_HW_r	1	Pass	1	1	R9.9
48021	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	21 - 1001_13 ini(98)_Uc3_HW_re	1	Pass	1	1	R9.9
48022	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	22 - 1001_14 Adjust_Offset_para	1	Pass	1	1	R9.9
48023	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	23 - 1001_15 Adjust_Offset_Para	1	Pass	1	1	R9.9
48024	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	24 - 1001_15 Start_embedded_T	1	Pass	1	1	R8.0
48025	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	25 - 1001_16 Start_embedded_T	1	Pass	1	1	R8.0
48026	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	26 - 1001_18 init(98)_Uc3_HW_r	1	Pass	1	1	R9.9
48027	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	27 - 1001_19 ini(98)_Uc3_HW_re	1	Pass	1	1	R9.9
48028	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	28 - 1001_20 init(98)_Uc3_HW_r	1	Pass	1	1	R9.9
48029	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	29 - 1001_21 ini(98)_Uc3_HW_re	1	Pass	1	1	R9.9
48030	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	30 - 1001_22 config(01)_Uc3_rec	1	Pass	1	1	R9.9
48031	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	31 - 1001_23 config(01)_Uc3_rec	1	Pass	1	1	R9.9
48032	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	32 - 1001_24 Read_Flashing_Toc	1	Pass	1	1	R9.9

CISS Test: This is a test station which is making an impact sound test for the product.

Mark the units as PASS/FAIL on this station in our WIP module.

On this station each single unit it is tested, and we store all measured values in EvaPROD

Id	Timestamp	SerialNumber	Station	StationType	StationNum	Material	TestDescription	TestValue	TestResult	USL	LSL	Format
48307	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	1 - 1001_1 Uc3_HW_Configurati	1	Pass	1	1	R9.9
48308	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	2 - 1001_2 Read_SW_Version_re	1	Pass	1	1	R9.9
48309	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	3 - 1001_3 Read_SW_Version_re	1	Pass	1	1	R9.9
48310	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	4 - 1001_4 config(01)_Uc3_requ	1	Pass	1	1	R9.9
48311	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	5 - 1001_5 config(01)_Uc3_recei	1	Pass	1	1	R9.9
48312	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	6 - 1001_6 init(98)_Uc3_HW_req	1	Pass	1	1	R9.9
48313	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	7 - 1001_7 ini(98)_Uc3_HW_rece	1	Pass	1	1	R9.9
48314	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	8 - 1001_8 Uc3_Activate_Modul	1	Pass	1	1	R9.9
48315	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	9 - 1001_9 Uc3_Activate_Modul	1	Pass	1	1	R9.9
48316	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	10 - 1001_10 config(01)_Uc3_rec	1	Pass	1	1	R9.9
48317	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	11 - 1001_11 config(01)_Uc3_rec	1	Pass	1	1	R9.9
48318	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	12 - 1001_12 init(98)_Uc3_HW_r	1	Pass	1	1	R9.9
48319	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	13 - 1001_13 ini(98)_Uc3_HW_re	1	Pass	1	1	R9.9
48320	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	14 - 1001_14 Adjust_Offset_para	1	Pass	1	1	R9.9
48321	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	15 - 1001_15 Adjust_Offset_Para	1	Pass	1	1	R9.9
48322	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	16 - 1001_15 Start_embedded_T	1	Pass	1	1	R8.0
48323	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	17 - 1001_16 Start_embedded_T	1	Pass	1	1	R8.0
48324	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	18 - 1001_18 init(98)_Uc3_HW_r	1	Pass	1	1	R9.9
48325	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	19 - 1001_19 ini(98)_Uc3_HW_re	1	Pass	1	1	R9.9
48326	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	20 - 1001_20 init(98)_Uc3_HW_r	1	Pass	1	1	R9.9
48327	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	21 - 1001_21 ini(98)_Uc3_HW_re	1	Pass	1	1	R9.9
48328	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	22 - 1001_22 config(01)_Uc3_rec	1	Pass	1	1	R9.9
48329	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	23 - 1001_23 config(01)_Uc3_rec	1	Pass	1	1	R9.9
48330	7/3/2020 8:26:48 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	CISS	Final Assembly	16	A2C15768304	24 - 1001_24 Read_Flashing_Toc	1	Pass	1	1	R9.9

Leakage Test: On this station we apply a specific air pressure inside of the product to be sure that is well seal.

Mark the units as PASS/FAIL on this station in our WIP module.

On this station each single unit it is tested, and we store all measured values in EvaPROD

Id	Timestamp	SerialNumber	Station	StationType	StationNum	Material	TestDescription	TestValue	TestResult	USL	LSL	Format
48468	7/3/2020 8:25:47 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	LEAKTEST	Final Assembly	15	A2C15768304	Pressure value	0.9	Pass	7.01	-0.01	R6.2
48469	7/3/2020 8:25:47 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	LEAKTEST	Final Assembly	15	A2C15768304	Carrier no	19	Pass	9999	0	R6.2
51320	7/3/2020 8:25:19 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015720701*=	LEAKTEST	Final Assembly	15	A2C15768304	Pressure value	0.8	Pass	7.01	-0.01	R6.2
51321	7/3/2020 8:25:19 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015720701*=	LEAKTEST	Final Assembly	15	A2C15768304	Carrier no	10	Pass	9999	0	R6.2
54841	7/3/2020 8:27:23 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730704*=	LEAKTEST	Final Assembly	15	A2C15768304	Pressure value	0.9	Pass	7.01	-0.01	R6.2
54842	7/3/2020 8:27:23 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730704*=	LEAKTEST	Final Assembly	15	A2C15768304	Carrier no	67	Pass	9999	0	R6.2

Final Test: This is a test station and is doing the final test of the product checking complete functionality of the product.

Mark the units as PASS/FAIL on this station in our WIP module.

On this station each single unit it is tested, and we store all measured values in EvaPROD

Id	Timestamp	SerialNumber	Station	StationType	StationNum	Material	TestDescription	TestValue	TestResult	USL	LSL	Format
48009	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	4 - 1001_1 Uc3_HW_Configurati	1	Pass	1	1	R9.9
48010	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	5 - 1001_2 Read_SW_Version_re	1	Pass	1	1	R9.9
48011	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	6 - 1001_3 Read_SW_Version_re	1	Pass	1	1	R9.9
48012	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	7 - 1001_4 config(01)_Uc3_requ	1	Pass	1	1	R9.9
48013	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	8 - 1001_5 config(01)_Uc3_recei	1	Pass	1	1	R9.9
48014	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	14 - 1001_6 init(98)_Uc3_HW_re	1	Pass	1	1	R9.9
48015	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	15 - 1001_7 ini(98)_Uc3_HW_rec	1	Pass	1	1	R9.9
48016	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	16 - 1001_8 Uc3_Activate_Modu	1	Pass	1	1	R9.9
48017	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	17 - 1001_9 Uc3_Activate_Modu	1	Pass	1	1	R9.9
48018	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	18 - 1001_10 config(01)_Uc3_rec	1	Pass	1	1	R9.9
48019	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	19 - 1001_11 config(01)_Uc3_rec	1	Pass	1	1	R9.9
48020	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	20 - 1001_12 init(98)_Uc3_HW_r	1	Pass	1	1	R9.9
48021	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	21 - 1001_13 ini(98)_Uc3_HW_re	1	Pass	1	1	R9.9
48022	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	22 - 1001_14 Adjust_Offset_par	1	Pass	1	1	R9.9
48023	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	23 - 1001_15 Adjust_Offset_Par	1	Pass	1	1	R9.9
48024	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	24 - 1001_15 Start_embedded_1	1	Pass	1	1	R8.0
48025	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	25 - 1001_16 Start_embedded_1	1	Pass	1	1	R8.0
48026	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	26 - 1001_18 init(98)_Uc3_HW_r	1	Pass	1	1	R9.9
48027	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	27 - 1001_19 ini(98)_Uc3_HW_re	1	Pass	1	1	R9.9
48028	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	28 - 1001_20 init(98)_Uc3_HW_r	1	Pass	1	1	R9.9
48029	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	29 - 1001_21 ini(98)_Uc3_HW_re	1	Pass	1	1	R9.9
48030	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	30 - 1001_22 config(01)_Uc3_rec	1	Pass	1	1	R9.9
48031	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	31 - 1001_23 config(01)_Uc3_rec	1	Pass	1	1	R9.9
48032	7/3/2020 8:22:08 AM	3#5WA959655A #H007S0523#*CODKTSR-TSR03.07.2015730702*=	SHAKER	Final Assembly	14	A2C15768304	32 - 1001_24 Read_Flashing_Toc	1	Pass	1	1	R9.9

BentPin: Because on the previous station from the flow we made a contacting of the product into a connector, on this station we need to check and assure that all the pins of the product are in a good shape.

Mark the units as PASS/FAIL on this station in our WIP module.

On this station each single unit it is tested, and we store all measured values in EvaPROD

Id	Timestamp	SerialNumber	Station	StationType	StationNum	Material	TestDescription	TestValue	TestResult	USL	LSL	Format
48470	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Carrier no	19	Pass	9999	0	R6.2
48471	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	File1	1	Pass	10	-10	R6.2
48472	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 1 X value	-34.48	Pass	-33.95	-34.85	R6.2
48473	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 1 Y value	2.85	Pass	3.25	2.35	R6.2
48474	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 1 Z value	7.63	Pass	7.8	7.4	R6.2
48475	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 2 X value	-31.86	Pass	-31.45	-32.35	R6.2
48476	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 2 Y value	2.82	Pass	3.25	2.35	R6.2
48477	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 2 Z value	7.66	Pass	7.8	7.4	R6.2
48478	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 3 X value	-34.52	Pass	-33.95	-34.85	R6.2
48479	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 3 Y value	-2.84	Pass	-2.35	-3.25	R6.2
48480	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 3 Z value	7.61	Pass	7.8	7.4	R6.2
48481	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 4 X value	-31.92	Pass	-31.45	-32.35	R6.2
48482	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 4 Y value	-2.76	Pass	-2.35	-3.25	R6.2
48483	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 4 Z value	7.63	Pass	7.8	7.4	R6.2
48484	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 5 X value	-28.94	Pass	-28.35	-29.25	R6.2
48485	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 5 Y value	4.5	Pass	4.88	3.98	R6.2
48486	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 5 Z value	6.97	Pass	7.1	6.7	R6.2
48487	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 6 X value	-27.11	Pass	-26.55	-27.45	R6.2
48488	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 6 Y value	4.55	Pass	4.88	3.98	R6.2
48489	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 6 Z value	6.96	Pass	7.1	6.7	R6.2
48490	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 7 X value	-25.2	Pass	-24.75	-25.65	R6.2
48491	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 7 Y value	4.57	Pass	4.88	3.98	R6.2
48492	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 7 Z value	6.97	Pass	7.1	6.7	R6.2
48493	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 8 X value	99	Pass	9999	-999	R6.2
48494	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 8 Y value	99	Pass	9999	-999	R6.2
48495	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 8 Z value	99	Pass	9999	-999	R6.2
48496	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 9 X value	-21.62	Pass	-21.15	-22.05	R6.2
48497	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 9 Y value	4.55	Pass	4.88	3.98	R6.2
48498	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 9 Z value	6.95	Pass	7.1	6.7	R6.2
48499	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 10 X value	-19.78	Pass	-19.35	-20.25	R6.2
48500	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 10 Y value	4.48	Pass	4.88	3.98	R6.2
48501	7/3/2020 8:28:33 AM	3#5WA959655A #H007S0523#*C0DKTSR-TSR03.07.2015730702*=	BENTPINCAMERA	Final Assembly	17	A2C15768304	Pin 10 Z value	6.95	Pass	7.1	6.7	R6.2

Laser Marking: On this station we are writing (using a laser) on the product the final label which is used by the customer to identify each product.

Mark the units as PASS/FAIL on this station in our WIP module.

3.4.1.2 Existing Infrastructure (current IT infrastructure)

Continental is using Manufacturing Infrastructure System 2.0 (MIS).

Every machine sends the measured values to traceability system via the network. For each process Continental store specific data into traceability database with more details already provided in the previous chapter.

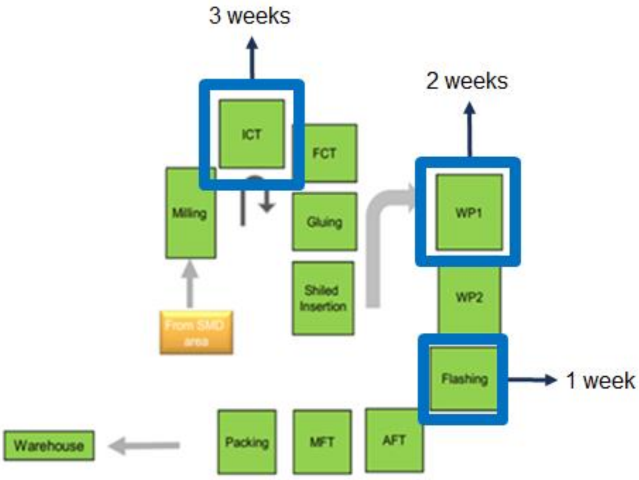
3.4.1.3 Pilot Specifications

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.

For each of the above problems (except the monitoring, which is a typical visualization issue) the DT modelling and need for cognition is detailed in the following scenarios:

Scenario #1: Self-diagnosis and predictive maintenance



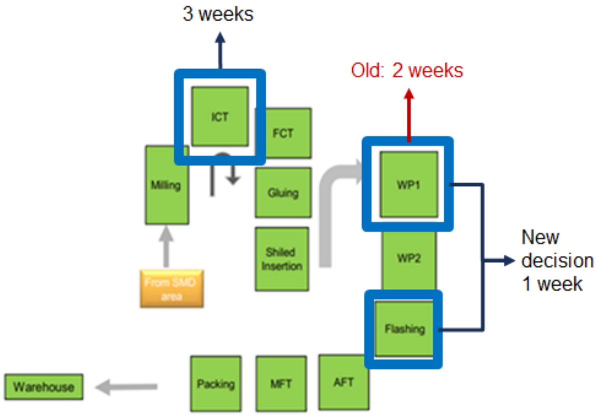
Description: this scenario refers to the ability of FACTLOG to diagnose a potential failure, predict the time of breakdown or getting the operation above the thresholds and identify the timeframe for predictive maintenance. This is similar to the anomaly detection described in the other cases.

Actors: All DTs (machine/workstations process)

Flow of information:

1. Data streams from **machine DT** are evaluated from the **reasoning engine**
   - Against the **machine DT's** existing behavioral model.
   - If there is a data that is outside the model, we need to utilize the data-driven approach
2. **CEP services** detect a potential risk (probability for a failure). CEP services might be assisted by the **process models,** which provide quality and other specifications of how the process/operation is run at the particular machine.
3. Through the **simulation and prediction services (root-cause analysis)**, we can propagate (predict) the behavior of the system considering the particular risk of failure of the machine. Initial prediction models will be based on historical data.
4. **Reasoning engine** provides as input the behavioral model of the machine.
5. As a result, the prediction and simulation services will provide the **necessary visualizations** to the end users.

Scenario #2: Aligning predictive maintenance with production plan



Description: once an anomaly is detected with the timeframe for maintenance, the process of production scheduling and planning need to be aligned in order to avoid costly and time-consuming idle times. The particularity is that if at least 1 machine gets out of order the whole production stops (for the context we are examining). Therefore, we need to check an optimal distribution of maintenance activities. This means that having as input the production plan and considering an alert about predictive maintenance, the decision should be to:

- check **which is the best time slot** to perform the maintenance
- Additionally, we could check whether we can "**group" the machines that need** predictive maintenance, for e.g.

- Machine 1 next week
- Machine 2 the week after

Actors: machine DT, Production line DT

Flow of information:

1. Cases of predictive maintenance have been identified for more than 1 machine DTs (see previous scenario).
2. The Production DT is aware of the machine DTs that have a need of prediction maintenance, together with the timeframes.
3. The Robust optimization methods are applied to identify the optimal matching and grouping of maintenance activities considering the different DTs timeframes and the plan of the production line DT.

Scenario #3: Optimized operational mode per machine

Description: Each machine should be able to identify its optimal operation mode (safe mode, on, off) according to the following information: production plan with ide times, energy behavioural model of the machine.

Actors: machine DT, Production line DT

Flow of information:

1. Information about production plan and real-time status of the machine DT are evaluated from the **reasoning engine** considering the below:
   - The actual status of the machine (idle? Working?)
   - The **machine DT's** existing energy behavioral model.
   - The plan in the day about the machine operation (if there is a need of production).
   - The operational behaviour of the machine (capacity, performance, etc.).
2. Through the **simulation and prediction services**, we can propagate (predict) the working status of the machine DT in the day considering the above information.
3. Using a combination of the **simulation/prediction** and **optimization services** we can identify whether the machine (at the particular time) need to continue working or stay in safe mode or stop taking also in consideration configuration times (stop/start) of the machine and energy cost.

In line with the above scenarios, maintenance and operations must be further combined with advanced analytics and robust optimisation methods to effectively coordinate maintenance (predictive or reactive) with production planning and scheduling.

In relation to optimization functionalities in the CONT case, the initial analysis yielded a number of findings highlighting the optimization needs and tools. The main pilot goal is to enable the creation of a production decision support system that takes under consideration maintenance scheduling in order to reduce production capacity by selecting machines to be maintained and even grouping maintenance actions together.

The electronics and car parts production process in the CONT case is a sequential process that involves specific and different process steps (corresponding to the flow from Surface mount operations to, printing circuit boards, to final assembling and lastly to packaging). These processes are conducted in specific machines and production lines and products have to follow a specific sequence of processing (some go through all machines while others can skip machines relevant to their production needs) as presented previously. Being able to monitor all machines/ stations in the process and aligning the production plan for all machines to their identified maintenance plan is a challenging flexible flowshop optimization problem that has to take under consideration maintenance operations.

At any given point of production, it may be identified that: (a) a machine may be presenting indications of a potential failure or (b) a machine needed for a newly arrived order is set for maintenance. On that account optimization needs to examine the process of production as a whole and given the identified timeframes available for maintenance (including the possible earliest and the possible latest) derive to a new production schedule that respects the maintenance constraints.

Based on the above-mentioned, the focal point of the optimization is to enable the dynamic scheduling of the production process taking under consideration the available timeframes for maintenance, so as to minimize the total cost of idle time of machines, or makespan or any other KPI suggested by CONT, based on:

- Detected anomalies in the machines involved
- Detected alerts for predictive maintenance from the machines
- Detected deviations in cycle times or product quality output.
- Scheduled maintenance activities
- Orders and Scheduled deliveries of finished products, and
- Energy consumption.

Having received input relevant to the aforementioned, optimization is responsible for utilizing the process-driven models and data-driven models in order to be able to derive optimal (or near-optimal) proposals for scheduling of the orders, taking under consideration the alerted maintenance events and preferred groupings for maintenance relevant to the production schedule.

In order to enable the aforementioned, the FACTLOG system is expected to be able to (a) incorporate predictive maintenance, (b) handle varied input and return the optimal schedule from and to the remaining FACTLOG tools and (c) perform the optimization tasks in a timely manner.

3.4.1.4 To be process flow

The implementation of the FACTLOG system in the pilot plant is expected to reduce/limit the number of down time caused by breakdown. The proposed decision support based on operational analytics would improve overall monitoring of machines and processes and identify optimization paths to prevent overload or failure. Mapping load critical points of machines capacity together with assessing their configuration flexibility and proposing dynamic capacity allocation would increase both the availability and the Overall Equipment Efficiency (OEE).

Moreover, the quality of the Pre and Final Assembly Line could be improved as the Operations Manager could forecast issues, create a backlog for preventive maintenance for wearable parts while planning and controlling the capacity of the equipment per process or per lot. Optimizing the usage of equipment and planning the processes on the Assembly Line based on “demand” and availability requirements has in impact also on the overall energy consumption and consequently on the costs. The feasibility of turning the machines into safe mode / idle based on production scheduling is also addressed.

3.4.1.5 Impact and Sustainability

The impact and sustainability are in correlation with KPIs and are two folded.

On the one hand business improvement via extending the life of involved equipment and reducing the costs related to energy consumption. By dynamic production scheduling, the shaving equipment capacity and the long-time planning of maintenance, will reduce significantly the number of breakdowns. This will increase the production performance while the energy consumption will be reduced.

On the other hand, a technological improvement starting from optimization processes based on operation analytics that are put in place on an Assembly Line. This action opens perspectives considering automated processes and replicability on other assembly lines.

Within FACTLOG project the demonstrator will be on a pilot line (Pre and Final Assembly line) while also considering extension possibilities.

3.4.2 KPI’s

3.4.2.1 Description of KPI’s

KPI 1-Machine downtime because of breakdowns

For an understanding of this KPI, screwing process is used as an example:

The process is implemented with state of the art technology components (e.g. screwdriver, screwdriver controller, axes systems for positioning, PLC for controlling the station).There is an operator that connects to a HMI interface and knows the status of the machine and the step sequence of the process. There is also a specific communication with MES system for system for traceability and monitor performance of the line and specific process parameters. When the operator sees an issue in HMI he needs to handle it manual so the machine is set in breakdown.

The focus of this KPI is to:

- Create a digital overview (environment) for the mechanical assembly are of the Final Assembly
- Line using cloud computing
- Anticipate the machine malfunction (parts ware down)
- Increase the availability of the equipment (higher OEE)

KPI 2-Total maintenance costs as a percentage of total operational costs

The example mentioned in KPI 1 applies to KPI 2.

The focus for this KPIs is to:

- Find the right balance for in terms of cost vs number of failures in the Final Assembly;
- Reduction of maintenance cost in terms of head count (HC) time used for Predictive, Preventive and Corrective maintenance in the Final Assembly Line

KPI 3-Energy consumption of idling machines as a percentage of total energy

If there is no production on an equipment and the previous ones in the process flow are not yet in production, then each equipment from the production line shall be put on a stand- by mode.

KPI 4-Overall Equipment Efficiency (OEE)

OEE = availability * performance* quality rate

This KPI is in relation with KPI 1 and KPI 2 through availability.

If the first 2 KPI’s are accomplished, then the KPI OEE will be improved.

3.4.2.2 Baseline and target values for KPI’s

Table 3.14 CONT's KPI baseline Values and Target Values

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%

3.4.3 Initial Datasets

identified datasets include:

- Data relevant to the floor plant
- Data relevant to the set of machines (operational data, output data) that are involved in all process steps
- Data relevant to the products (process parameters, measured values, product reaction),
- Data relevant to produced alerts.

- Data relevant to the set of orders and production plan
- Data relevant to the maintenance schedules and relative information (wearing of tools, deviation from accuracies observed)
- Data relevant to energy consumption.

3.5 Steel Sector: Pilot Case by BRC

3.5.1 Reference Scenario

BRC manufactures bespoke products for the construction industry with a lead-time of 5-7 days where each batch is unique and can be up to 2 tonnes of steel in one product batch. Under BS8666 these can be in the form of simple straight bar, “U” shaped bars to complicated 99 shape codes where it could be 3D shapes. The process involves cutting and shaping various diameters of steel reinforcing bar to customer requirements using various manual or automatic operations.

There are two main challenges that BRC face as a business that the FACTLOG toolset would prove very beneficial with the implementation. The first of these is the problem that there is very little live data available from shop floor machines and cranes that allows problems to be analysed and resolved quickly. Currently production and maintenance planning are done on an ad-hoc basis and the application of optimization techniques would not be dynamic in nature as all data would be historical. The intention is to provide an interface for some of the machines so the live data will be collected and tracked which will in turn enable the digital twin to become a real time application of the processes being developed by the FACTLOG project. This would allow the FACTLOG system to make real time decisions about the status of the machines and provide optimized production schedules for each machine and process line, whilst producing detailed maintenance plans based on the machine condition monitoring that will be provided.

A second problem is optimization of crane movement and tracking of batch storage on the shop floor. When linked to a FACTLOG system, crane movement could be optimized together with part storage. This would provide a highly efficient part tracking and loading system directing operators to a set of coordinates to pick up the parts for each consignment, the trailer loading would also need to be optimized to provide efficient delivery to separate customer sites.

3.5.1.1 Context: The business case and As-Is process flow

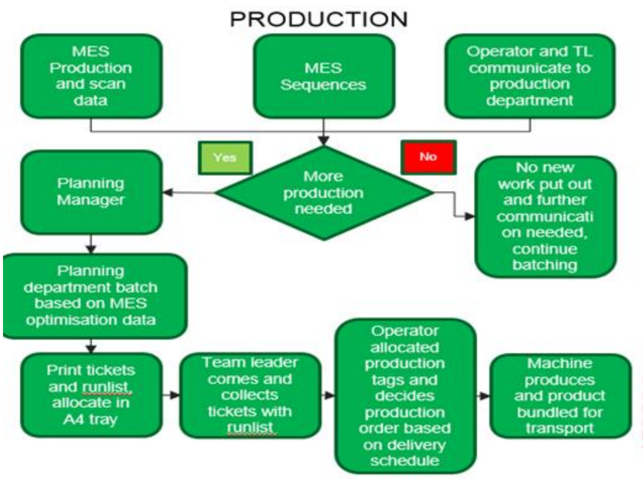


Figure 3.16 BRC Pilot As-Is Production Process Flow

The production process on the whole is a paper exercise, the MES system provides an updated product path for individual batches based on machine vendor cycle time predictions. When the current in process batches are nearing completion or there is a requirement to add production batches, the production-planning department produces an optimised plan based on available machines, this results in a group of tickets being produced which are collected by the production team leader to be distributed to machine operators. The operator on receipt of their batch of tickets orders them for processing based on the delivery schedule.

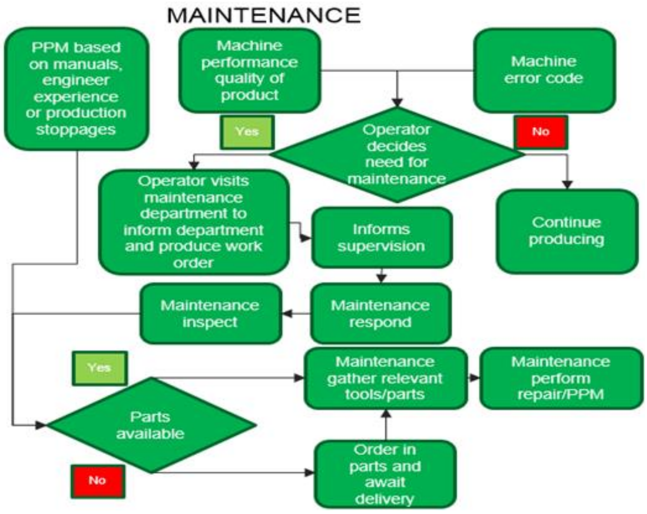


Figure 3.17 BRC Pilot As-Is Maintenance Process Flow

The maintenance operating system is also purely manual process where experience or vendor maintenance plans are used to produce a preventative maintenance plan for each of the machines or cranes. Breakdowns are reported by the machine operators and depending on the severity of the breakdown determines if the machine can carry on producing or has to be put on stop awaiting repair/parts.

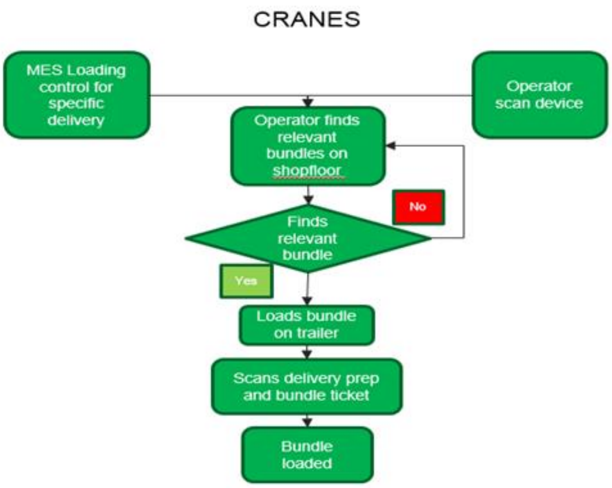


Figure 3.18 BRC Pilot As-Is Crane Operation

The crane operation is dependent on the MES loading function which shows the product that is required/ready to be loaded onto trailers from the sequence (product batch) and what is loaded however once moved into a warehousing step does not record location. This can result in lengthy delays while a crane becomes available for unloading a machine or while the crane operator locates a batch of product which has been stored on the shop floor to be loaded onto a trailer.

3.5.1.2 Existing Infrastructure (current IT infrastructure)

The current information that is available by area is below:

Production:

- Scan tags produced by the current MES system track where the bar is through production process but not in relation to a shop floor map
- Barcode scanners on machines tell the system where the batch is being produced and is currently being produced but no real-time tracking of progress on the batch
- The number of tones produced on a machine will be recorded by the system each time a barcode for a batch is scanned in
- The current status for the workstation which is entered manually into the machine

Logistics:

- What batch is finished in the process and is waiting to be loaded
- What is left to load on a delivery
- What time the batch has been scanned onto the trailer

Maintenance:

- A paper-based system is currently in use for the maintenance department
- Development of a bolt on for the MES system in relation to maintenance and work orders is being looked at but will involve mainly manual intervention

Machine monitoring:

There are currently no automated systems in place that monitor the production machines or processes. On that account, BRC is currently in the process of developing a system based on Industreweb that will connect to the existing machine controls and save process and machine condition data to the BRC data base. This detailed information will then be available for FACTLOG to operate on the data provided, for the machine monitoring system the plan is to connect the EVG bar bending machine as the pilot. The machine monitoring system will have the following sensors:

1) Energy meter monitoring the incoming power the machine is using for different operations such as bending and feeding the bar. This will provide readings for average power, peak power and cumulative power (energy) used for each step of the machine operation
2) Hydraulic pressure and temperature transducers which will monitor the parameters as the machine cycles.
3) A time stamp will be recorded for the start of each batch and the time duration in milliseconds will be recorded for step of the machine operation.

4) It is planned to install an accelerometer which will measure the machine vibration occurring during the machine cycle.

It is hoped that this data will allow the FACTLOG toolset to analyse the machine state of health and learn to predict failures prior to them occurring so these can be rectified in a controlled and planned manner allowing the resulting downtime to be minimised

3.5.1.3 Pilot Specifications

An overall optimisation of production scheduling taking under consideration current orders, available machines, stock data, transport requirements, available operators, existing production plans and PPM requirements is the ultimate scenario that FACTLOG envisages, based on hierarchies of the pilot needs.

The FACTLOG system should provide an optimised production schedule. Based on the input parameters provided by FACTLOG, the decision variables of the optimization model will outline a comprehensive and detailed plan that maximises utilisation in accordance with delivery expectations. In order to provide a best in class sustainable process, quality issues and availability of stock variants required for each batch also need to be taken into account by the optimisation process in order for the scrap levels to be minimised when possible.

The Cognitive process should also include monitoring and predicting machine breakdowns which is fed back to the maintenance department for planning purposes and into optimisation process to allow maintenance windows to be implemented depending on the seriousness and expected duration of the resulting stoppage.

The crane DT when linked to the production DT will then be able to predict and optimize the crane movements to service load and unload operations to the cranes and other stock movement requirements, while selecting and recording storage locations for the stock depending on batch, consignment and transport requirements. As each trailer is assigned loads and destinations, an optimised pick list should be generated directing the crane operator to each batch for the consignment which is to be picked in order of preferred loading order (size and weight) and destination in the case of multiple consignments on a trailer.

The need for Cognitive Digital Twins

The case of BRC is summarized into the following four problems:

d) How to detect a trend in performance or availability in each BRC machine or crane making the best usage of data flows (from the machines and cranes and external ones)?
e) Once an anomaly is detected in one of the machines (e.g. coil, bending machine) or cranes how would that effect the production of the upcoming new order and its' production?
f) How can we have a production schedule that takes under consideration machine availability and maintenance activities?
g) As the cranes are an important part of production how can we take under consideration their movement within the factory?

When considering the above issues, the reference scenarios for the operation of Cognitive Digital Twins can be produced. For each of the scenario in the following, we identify the actors and expected flow of information (from information sources, to cognition and optimization and finally visualizations to the end user).

Scenario #1: New Data Streams and Storing

Description: As in the previous cases, this scenario refers to how information is collected from different information sources and stored in FACTLOG in a meaningful way to create knowledge about the performance of the modelled assets/ processes.

Actors: All DTs (either asset and/or process)

Flow of information:

1. Information about Orders, Machines' Status, Cranes etc. is passing through the **message bus** coming from different sources (sensors, positional data / movement data of cranes, existing MES system, digitized input of currently offline stored information). This is done using data connectors created for each of the information source.
2. **Data abstraction services** are transforming information into a common format (using FACTLOG semantic model).
3. **Cleaning services** will store the preliminary processed data into the **persistence level**.
4. Advanced cleaning services can also be utilized using data-driven models (through cognition services).

Scenario #2: Anomaly detection

Description: Once information is collected, through Cognition we can identify potential trends or even failures in performance of a DT.

Actors: Machine Digital Twin, Crane Digital Twin, Production Digital Twin

Information flow:

1. Data streams from **machine DT / crane DT** are evaluated from the **reasoning engine**
    a. Against the **machine / crane DT's** existing behavioral model.
    b. Against the batch that needs processing and **Productions' DT** process step behavioral model.
    c. If there is a data that is outside the model, we need to utilize the data-driven approach
2. **CEP services** detect a potential risk (probability for machine (or crane) failure or maintenance in the course of the order producing). CEP services might be assisted by the **process models** which provide quality and other specifications of how the process/operation is run at the particular machine.
3. Through the **simulation and prediction services (root-cause analysis)**, we can propagate (predict) the behavior of the system considering the particular risk of failure of the machine / crane etc. Initial prediction models will be based on historical data.
4. **Reasoning engine** provides as input the behavioral model of the machine.
5. As a result, the prediction and simulation services will provide the **necessary visualizations** to the end users.

Scenario #3: Production Scheduling taking under consideration availability of machines

Description: In case of an anomaly detection in machines, FACTLOG needs to understand the affected DTs (assets and/or processes) and perform an impact assessment and afterwards to be able to utilize the DTs (and respective physical counterparts) in the production.

Actors:

- Machine DTs: Machine Digital Twin
- Process DTs: Production Digital Twin

Information flow:

1. Data streams from **machine DT** are evaluated from the **reasoning engine**
    - Against the **machine** existing behavioral model.
    - Against the batch that needs processing and **Productions' DT** process step behavioral model.
    - If there is a data that is outside the model, we need to utilize the data-driven approach
2. **CEP services** detect a potential risk (probability for machine failure or maintenance in the course of the order producing). CEP services might be assisted by the **process models** which provide quality and other specifications of how the process/operation is run at the particular machine.
3. In case of a potential anomaly, the machine DT informs (through DT<->DT messaging the production process DT in which it belongs to.
4. Through the **simulation and prediction services (root-cause analysis)**, we can propagate (predict) the behavior of the system considering the particular risk of failure of the machine etc. Initial prediction models will be based on historical data.
5. **Reasoning engine** provides as input the behavioral model of the machine and the production process.
6. **CEP services** inform **Optimization** about machine status (GO / NO GO on that machine and all other available machines).
7. **Optimization** proposes new production schedule that takes under consideration the machine availability.
8. *The* ***simulation services****, utilizing* **production DT** and **machines DTs** *and Optimization Output and remaining data can propagate (predict) the behavior of the system considering all orders to predict possible outcomes of KPI TPMH.*
9. As a result, the analytics, prediction, optimization and simulation services will provide the **necessary visualizations** to the end users.
10. If such solution is ok (against KPIs) then the proposed optimization is validated. If not, or something changes restore feasibility of the production plan by go to step (2)
11. The **reasoning engine** is updated with new knowledge about the behavior of the **machine DTs** and **process DTs (**feedback loop from **Optimizer** to **reasoning)**

Scenario #4: Production Scheduling taking under consideration availability of machines and crane movement

Description: As cranes are responsible to load / unload the machines there are at times the cause of bottlenecks in the sense that they need to (a) be available at the time of need – when a new product is produced (b) place it in specific general laydown area but not currently conducted at a predefined location. In order to mitigate that issue different location identification sensors are envisaged to identify location and movement data of the cranes. Therefore, in the case of an anomaly detection in machines and an anomaly detection in the location / operation of the cranes FACTLOG needs to understand the affected DTs (assets and/or processes) and perform an impact assessment and afterwards to be able to utilize the DTs (and respective physical counterparts) in the production.

Actors:

- Machine DTs: Machine Digital Twin, Crane Digital Twin
- Process DTs: Production Digital Twin

Information flow:

1. Data streams from **machine, crane DT** are evaluated from the **reasoning engine**
    a. Against the **machine, crane** existing behavioral model.
    b. Against the batch that needs processing and **Productions' DT** process step behavioral model.
    c. If there is a data that is outside the model, we need to utilize the data-driven approach
2. **CEP services** detect a potential risk (probability for machine failure or maintenance in the course of the order producing / probability of a crane to be for maintenance or not be moving appropriately). CEP services might be assisted by the **process models** which provide quality and other specifications of how the process/operation is run at the particular machine.
3. In case of a potential anomaly, the crane DT or machine DT informs (through DT<->DT messaging the production process DT in which it belongs to.
4. Through the **simulation and prediction services (root-cause analysis)**, we can propagate (predict) the behavior of the system considering the particular risk of failure of the machine or failure of crane etc. Initial prediction models will be based on historical data.
5. **Reasoning engine** provides as input the behavioral model of the machine and the production process.
6. **CEP services** inform **Optimization** about machine status (GO / NO GO on that machine and all other available machines). Additionally, it informs about the availability and appropriate operation of the cranes.
7. **Optimization** proposes new production schedule that takes under consideration the machine availability and cranes performance.
8. *The **simulation services**, utilizing* **production DT** and **machines DTs** and **Cranes DT** *and Optimization Output and remaining data can propagate (predict) the behavior of the system considering all orders to predict possible outcomes of KPI TPMH.*
9. As a result, the analytics, prediction, optimization and simulation services will provide the **necessary visualizations** to the end users.
10. If such solution is ok (against KPIs) then the proposed optimization is validated. If not, or something changes restore feasibility of the production plan by go to step (2)

11. The **reasoning engine** is updated with new knowledge about the behavior of the **machine DT** and **Crane DT** and **process DTs (**feedback loop from **Optimizer** to **reasoning)**

3.5.1.4 To be process flow

Generalised "to be" process flow for production and maintenance systems (see Figure 3.19).

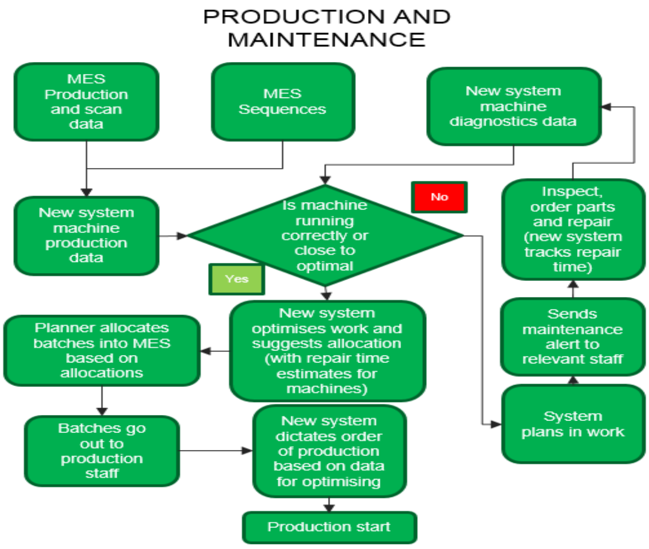


Figure 3.19 BRC Pilot To-Be Summarised Production Process Flow

Generalised crane "to be" process flow (see Figure 3.20).

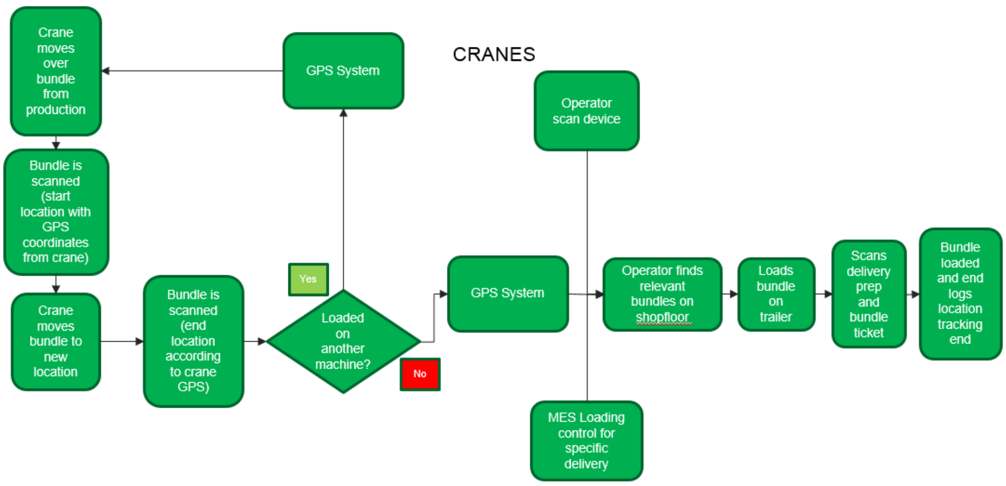


Figure 3.20 BRC Pilot To-Be Crane Operation

Detailed "to be" process flow diagram showing integrated optimisation and cognition services required

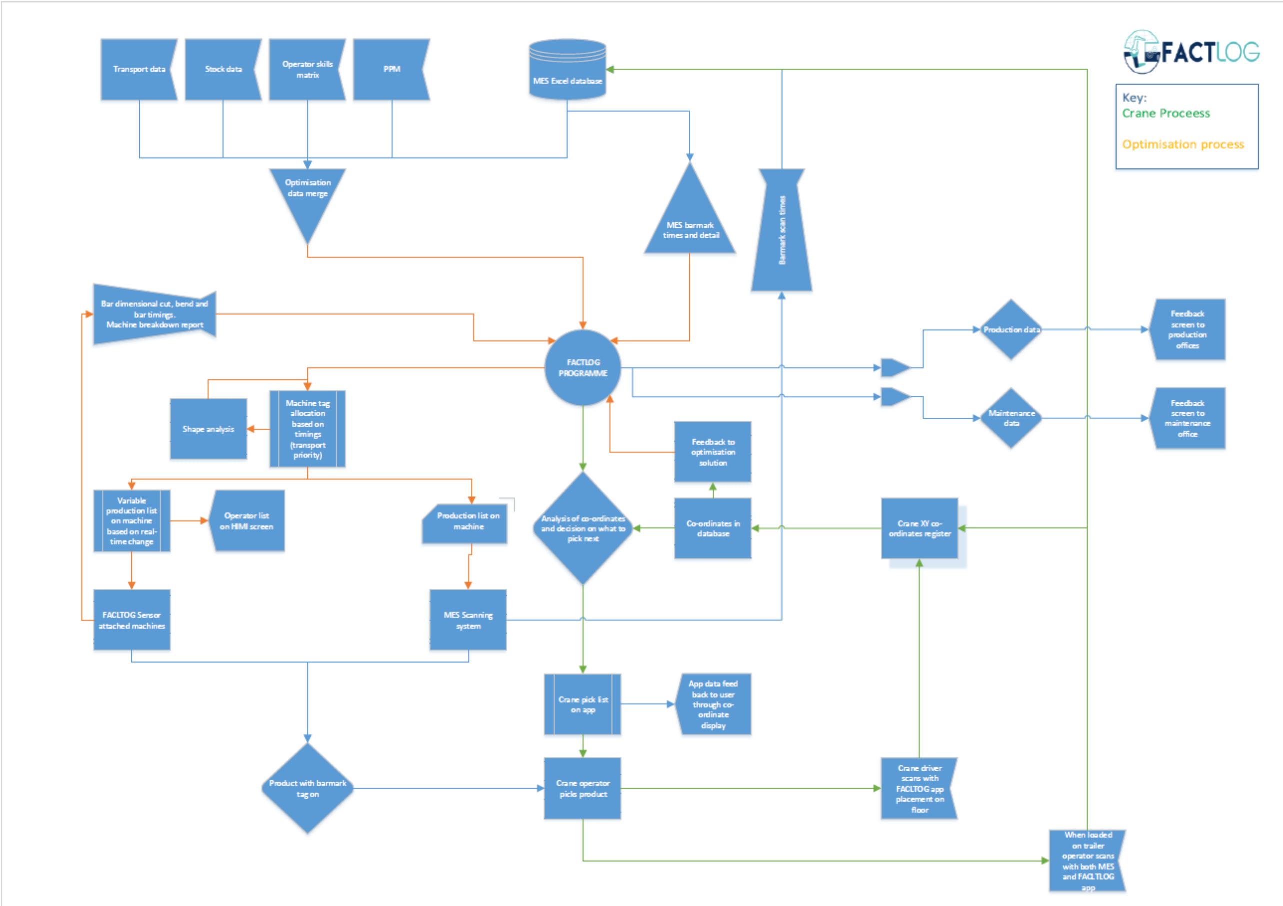


Figure 3.21 BRC Pilot Detailed To-Be Process Flow

3.5.1.5 Impact and Sustainability

BRC's *Customer Service Charter* states that we are targeting perfect service. To be able to provide this the production process needs to be efficient and sustainable. The FACTLOG tools have the potential to greatly improve the production and maintenance planning process and overall crane efficient utilisation. These improvements will increase the overall factory efficiency and in turn reduce both energy and operational costs which in turn will increase the profitability and hence sustainability of the business as a whole.

3.5.2 KPI's

3.5.2.1 Description of KPI's

The main KPI's in the business are TPMH (Tonnes per person-hour), Tonnage, operational costs and energy consumption. TPMH and tonnage go hand in hand with TPMH being efficiency targets and tonnage being the output of the business. The Newport business unit has put out 1686 tonnes over the last 6 months at an average of 0.76 Tonnes per person-hour. At peaks it can reach up to around 2000 tonnes and hit a TPMH of 0.9, we look to hit this consistently through efficiency improvements but due to legacy machinery and current technology better overview is needed. Through efficiency improvement comes overall operational cost improvement and energy efficiency hence the advancement in this would greatly benefit in main business KPI's and allow the business to improve environmentally. The key factors currently causing challenges for the business is the use of historical data and no live view status of the shop floor, Personnel informing maintenance of breakdowns and storage of bar within the factory. These affect main processes areas logistics (crane movements), production process (Shearing, Manual bending and De-coil) and Maintenance.

3.5.2.2 Baseline and target values for KPI's

Table 3.15 BRC Pilot KPI's Pertinent to FACTLOG Project

KPI	Today	With FACTLOG
TPMH	0.76	0.9
Tonnage	1686	2000
Energy (MWh)	127.91	121.51

3.5.3 Initial Datasets

Types of products (in terms of diameters and/or other characteristics) each department makes.

- Detailed data for the specifications of each type of machine.
- Processing times for machines with little or no human intervention.
- Manually operated machines:
  - Present: Use expert opinions.
  - Future: Installed sensors.
- Past data of time scans when they exist.
- Transport data.
- Quality issues:
  - Present: Use expert opinions
  - Future: Installed sensors
- For a list of past orders: Bill of materials, availability of stock for the order.
- Past demand data.
- Set up times:
  - Present: Discuss with experts and get estimates for each shape code.
  - Future: Installed sensors
- Energy consumption data for the factory as a whole and data from individual machines which will be gathered by the installed sensors.

4 Appendix

4.1 AS-IS and TO-BE process of JEMS

Process:	waste2fuel		AS IS: Role in the process (RACI)				TO-BE: Role in the process (RACI)									
Process	**Subprocess**	**Comment**	**site manager**	**shift manager**	**engineer**	**worker (3)**	**site manager**	**shift manager**	**engineer**	**worker (1)**	**1st L support: automation with AI**	**2nd L support: CCC**	**3rd L support: Technical team**	**4th L support Officiel service**	**Platform - predictive maintenance**	**Platform - Optimisation**
Feedstock procurement	Procurement planing	Identifying needs	I	A R		R		A R			I					
	Selecting supplier	RFI	A R	R	C			A R			I					
		RFP	A R	R	C			A R			I					
		negotation	A R	C				A R			I					
		RFQ	A R	R	C			A R			I					
		Contract	A R	I	I			A R			I					
	Ordering	internal purchase request	R	A R		C		A R			I					
		order	A R	R	I			A R			I					
	Logistics	delivery	I	A		R		A		R	C					
		quality control	I	A	I	R		A		R	R					
		unloading		I		A R				A R	R					
		paper work	I	A R		R		A		R	R					
		storing		I		A R				A R	R					
Feeding	inspecting and removing inorganic particles	Detecting an removing particles before entering the process		R	C	A R				A R	R					
	feedstock dosing into carrier oil			R	I	A R				A R	R					
	controling	viscosity, RPM, level …		R	I	A R				A R	C				C	R
	detecting for process flow anomalies		I	R	C	A R				A R	C				R	
Drying	controling	RPM, torque, temperature, pressure, level, viscosity, pH…		R	I	A R				A R	C				C	R
	feedstock mixing and drying			R	I	A R				A R	R				C	
	detecting for process flow anomalies		I	R	C	A R				A R	C				R	
Processing	controling	RPM, temperature, pressure, level, viscosity, pH…		R	I	A R				A R	C				C	R
	feedstock processing			R	I	A R				A R	R				C	
	detecting for process flow anomalies		I	R	C	A R				A R	C				R	
Distiling I	controling	temperature, pressure, level, viscosity, fuel quality …		R	I	A R				A R	C					R
	detecting for process flow anomalies		I	R	C	A R				A R	C				R	
	fuel testing		I	R	A R	R		A R			C					R
Distiling II	controling	temperature, pressure, level, fuel quality …		R	I	A R				A R	C					R
	detecting for process flow anomalies		I	R	C	A R				A R	C				R	
	fuel testing		I	R	A R	R		A R			C					R
Sludge removal	controling	temperature, pressure, level, time, dryness…		R	I	A R				A R	C					R
	identification of sludge level (high)		I	A R	I	R		A R			R					C
	initialization of plant safe mode (shut-down)		I	A R	I	R		A R			R					C
	sludge discharge			R	I	A R				A R	R					C
	initialization of plant start-up		I	A R	I	R		A R			R				C	
	stabilization of process parameters		I	A R	I	R		A R			R					C
	sludge removal to external storage			R	I	A R				A R	R					C
	detecting for process flow anomalies		I	R	C	A R		A R			C				R	
Fuel storing	controling	temperature, level, fuel quality …		R	I	A R				A R	C					R
	sampling fuel for on-site testing		I	R	A R	R				A R						
	sampling fuel for Lab testing		I	C	A R					A R	R					
	storing			I		A R				A R						
Fuel sales	sales planning	market assesing	A R		C			A R			C					
	sales process	RFP	A R		I			A R			C					
		negotation	A R		R			A R			C					
		RFQ	A R		I			A R			C					
		contract	A R	I	I	I		A R			C					
		receiving & processing order	I	A R		R		A R			C					
	sales logistics	fuel loading		I		A R				A R						
		paper work	I	A R		R		A R		C	R					
Regular inspection	Search for potential irregularities		I	A R	C	R		A R			C		I		R	
	status analyses		I	C	A R			A R			C		I		R	
	anomaly detection		I	C	A R			A R		R	C				R	
	trend detection							A R							R	
	incident prediction							A R							R	
	plant walk-arround		I	A R	I	R		A R		R						
	recording status		I	A R	I	R		A R		R	C					
	reporting		I	A R	I	R		A R		R	C				R	
Incident management	trend analyses							A R							R	
	receiving alarms		I	A R	I	R		A R			R	I	I			
	reading of deviations		I	A R	C	R		A R			C	I	I		R	
	triggering an incident elimination protokol		C I	R	A R	R		A R			C		I		R	
	recording status		I	C	A R	I		A R			C		I		R	
	reporting		I	C	A R	I		A R					I		R	
Daily /regular maintenance	workorder for daily assignments			A R	C	I		A R			R					
	perfoming activities acc. to work-order			A R	I	R		A R		R	R		I			
	recording status		I	A R	I	R		A R			C				R	
	reporting		I	A R	I	R		A R			C				R	
Process administration			A R	R	R	R		A R		C	R	C	C			

Figure 4.1: The RACI matrix containing the detailed description of the JEMS waste2fuel process

4.2 AS-IS and TO-BE process of TUPRAS