BE in CPPS

Innovation Action Project

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# D8.5 – Rhône-Alpes Regional Ecosystem Business Assessment and Recommendations

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## Deliverable Peer review summary

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## Table of contents

## Executive summary

D8.5 report includes the first sessions of business assessment (M15) according to the methodology in alignment with the other ecosystems of the BEinCPPS project. The report includes an overview of such methodology.

The report contains an overview of the industrial champion for the Rhône-Alpes (now called Auvergne-Rhône-Alpes) region, starting with an overview of the Georges Pernoud group and a peek of the industrial sector where it performs – the fabrication of industrial tooling for plastics manufacturing, more specifically molds for plastic injection. The report shows that, despite the Georges Pernoud group being an SME, it has a large innovation potential to drive groundbreaking experiments with cyber-physical productive systems (CPPS) such as the one for BEinCPPS, the Smart Mold. The report continues by explaining the regional context of the Auvergne-Rhône-Alpes region, in which the industrial toolmaking sector is one of the first drivers of the regional economy.

The report continues to explain the experimentation plan, detailing each one of the executed experiments up to M15, corresponding to the definitive deployment of the first iteration of the pilot, and the different requirements sought to be validated. The validation, as per the methodology, is evaluated in terms of the key-performance indicators (KPIs) before the experimentation (i.e. production processes without the smart mold), the target KPIs, and the actual KPIs as they were measured in the experimentations. A positive outcome is put in evidence, as every business requirement targeted for the first iteration has been fulfilled. Comments are provided for each measurement.

The report specifies the business requirements yet to be addressed by the pilot in the second iteration. These include five business requirements in which the stakeholders of WP8 are actively working on at the time of writing of this report.

The business assessment complemented by a further analysis for key lessons learnt and useful recommendations for CPS adoption in SMEs are reported. These include:

- When SMEs plan pilots to assess the capabilities of CPPS, it is important to foresee the skills that will be needed for the development of any CPPS, which is not limited to a software development but also hardware, so skilled developers in electronics will also be required to successfully adopt cyber-physical system technologies. This is particularly the case in greenfield developments in SMEs, where production lines do not count with any digital equipment such as sensors or embedded systems for industrial automation (instead of brownfield developments in mid-caps and large production companies), and these must be deployed from scratch.
- The components of the digital platforms used in the experimentation, as specified in the IT assessment documents submitted along this report, show a high level of maturity but the industrial champion still needed a strong support from the components' developers, as the publicly available documentation was still not enough. Moreover, some doubts arose

regarding the robustness of some of these components, as in several cases they did not function properly and they didn't provide enough feedback with information to solve the problem.

- On-site networking and communications aspects must be also foreseen in greenfield developments, especially in SMEs where a device-factory-cloud architecture is still not clearly defined, and connectivity of equipment to private clouds is not available because it has not been needed before; however it is indispensable to leverage the benefits of cyber-physical productive systems.

# 1 Introduction

## 1.1 Introduction

This documents provides the assessment of the final results achieved in the Champion experimentation, including a description of the defined key performance indicators measured. The lessons learned during the process, the results achieved and recommendations for the implementation of CPPS are also documented.

In particular, after a description of the followed methodology in section 1, the Rhône-Alpes Champion is described in section 2. The experimentation plan is deeply described in section 3, while section 4 is dedicated to the results of the experiments and section 5 to the lessons learnt.

## 1.2 Methodology

To gather BEinCPPS champions' business requirements, the project follows the well-known spiral development approach, described in Figure 1. This approach essentially parallelizes the development activities of the classical 'waterfall' approach, from requirements to system design to verification and validation. Indeed, the spiral approach allows a continuous review of the development results and user requirements in order to better deliver added value to the users and the stakeholders of the system.

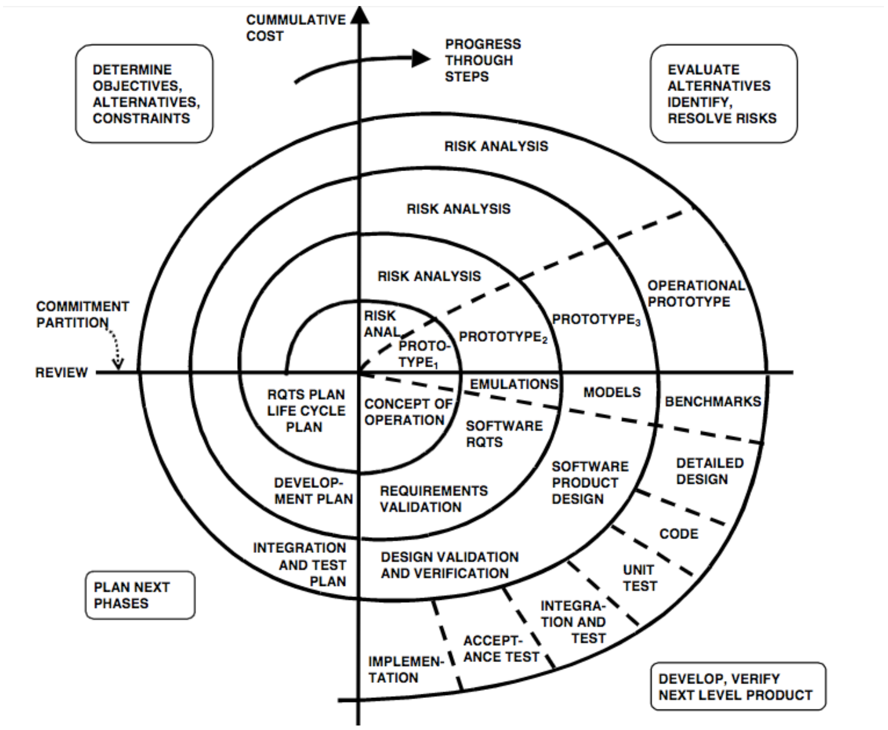


*Figure 1: Boehm, B. (2000) Spiral Development: Experience, Principles, and Refinements, SPECIAL REPORT CMU/SEI-2000-SR-008*

In particular, BEinCPPS business requirements, refer to the scenarios involved in the area of intervention of each champion, which have been studied and specified by the analysis of the correspondent business processes and sub processes.

The main phases of BEinCPPS requirement engineering cycle are presented in Figure 2.

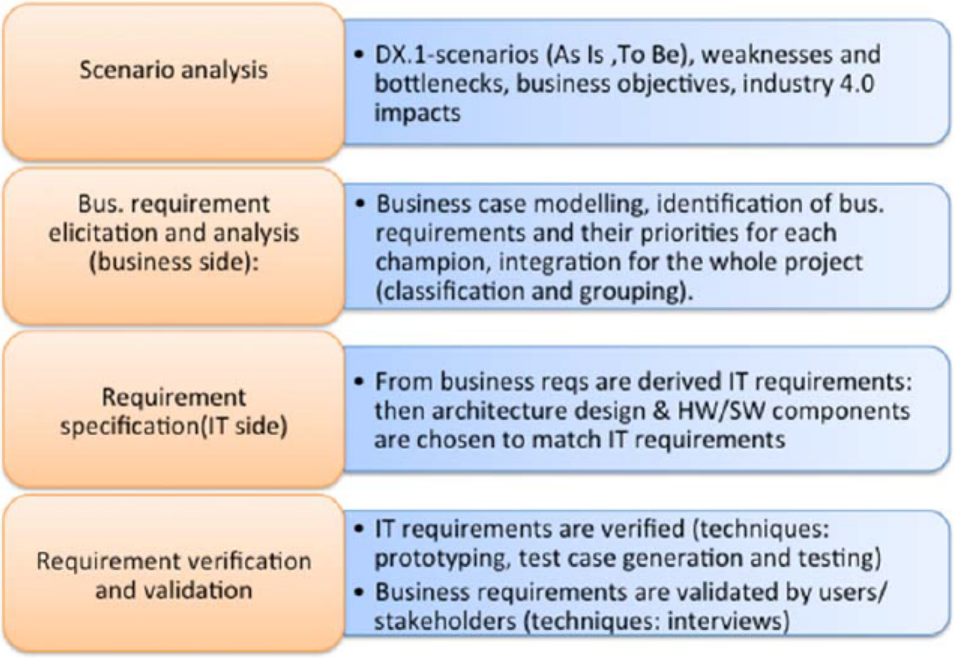


*Figure 2: BEinCPPS business engineering (adapted from Sommerville, 2007)*

The first phase is related to the “Scenario analysis”, where each champion identifies the relevant CPS-ization scenarios, by building up the weakness and bottlenecks of the “As is” situations, taking into account their business objectives and impacts.

The second phase concerns the “Business requirements elicitation and analysis”. During this phase the business processes that support the identified scenarios are analyzed by means of state of the art methods (use case models, BPMN, extended actigrams, UML, etc) with the BEinCPPS available design tools. Business requirements are organized in a database, for further processing, integration and classification.

In the third phase, “Requirements specification”, IT requirements are devised by the technical partners on the basis of the business requirements. Architecture design occurs in a way that IT requirements are matched by the IT artifacts (software and hardware) that build up the BEinCPPS architecture, with the support of proper customized activities for the non-standard components and interfaces with legacy systems.

The last phase is the “Requirements Verification and Validation”.

Verification and Validation (V&V) is the process of providing evidence that the software and its associated products satisfy system requirements allocated to software at the end of each life cycle activity, solve the right problem and satisfy intended use and user needs.This methodology aims at verifying, validating and evaluating a software product from its conception to final release and implementation in real-life, trial settings. In general, Verification ensures that the product is being built according to the requirements and design specifications, while Validation makes certain that the product actually meets the user’s needs, the specifications were correct in the first place and the product fulfils its intended use when placed in its intended environment. In this specific case verification is enacted with test case development and testing (matching system functionalities to IT requirements) where validation covers how and how much the system functionalities match the user/stakeholders needs identified in the first phases of the project.

General understanding of V&V process:

Verification: do the IT artifacts deployed match the technical specification and expectations?

Validation: do (and to what extent) the solution deployed matches the user/business requirements and expectations?

Figure 3 shows how the BEinCPPS approach is specifically enacted in the aforementioned spiral approach. The figure presents the first half of the project, with the final requirements documentation being one of the inputs of the project second half that will begin with a second scenario analysis, built on the previous outcomes (the requirement database and requirement document which contains the verification and validation results).

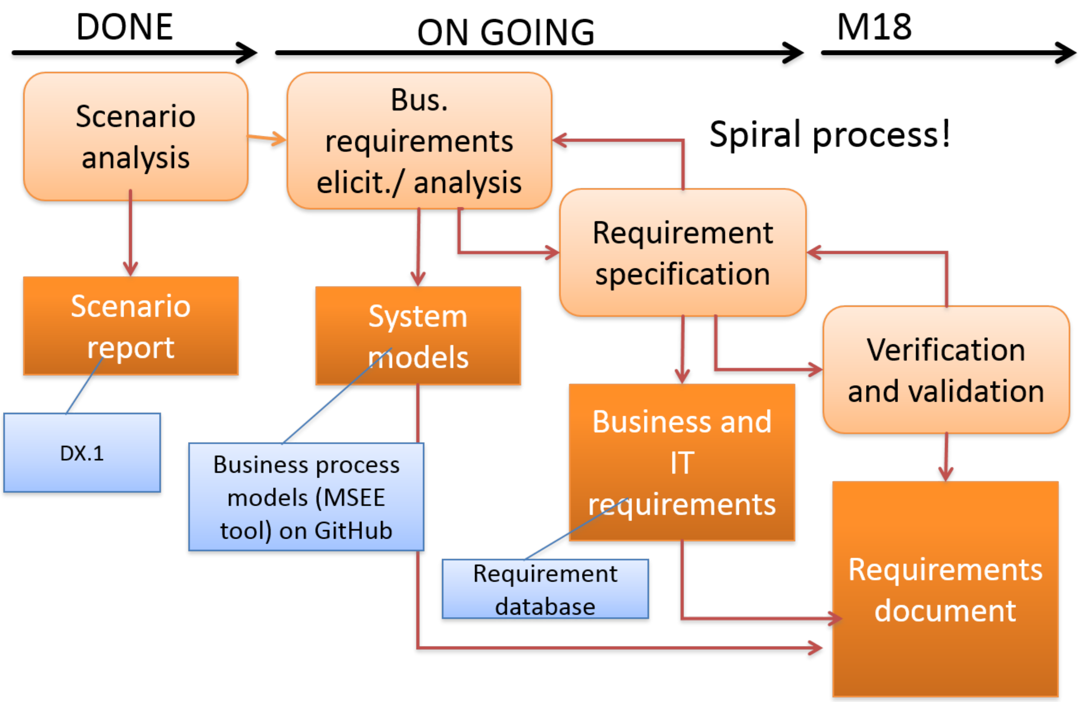


*Figure 3 Spiral approach of BEinCPPS reqs. engineering method*

Figure 4 shows the data structure supporting the project, especially the scenario analysis, requirements elicitation and requirement specification. The model includes as well the repositories, such as Github, which are used in the project to share the related information.

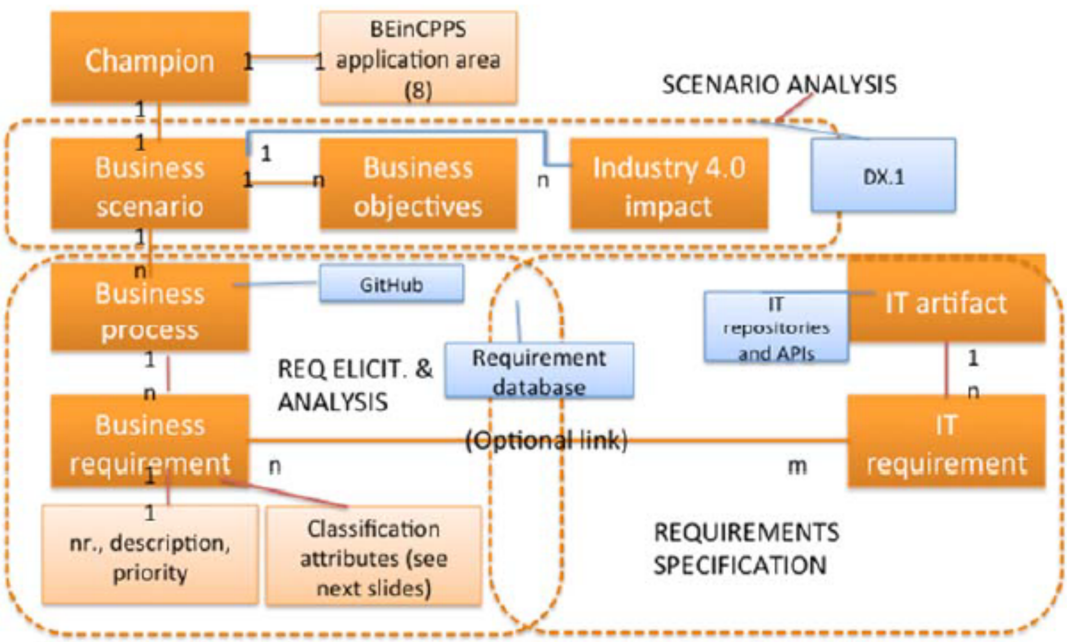


*Figure 4 BEinCPPS requirement eng. data structure*

Each champion has identified one business scenario or area of intervention, with its specific business objectives and KPIs, and industry 4.0 impacts. Recount of these activities, building up the 'Scenario analysis' has been included in the five champions Deliverables Dx.1 due M3.

After this phase, the scenarios, studied as a chain of business processes that make up the whole business process of the intervention area, have been linked with specific objectives and indicators: the most effective way for this is also to assign specific business objectives and indicators for each business process. Then, for each business process a list of business requirements has been identified, in order to identify precisely how the system/solution deployed will support the transformation of the old "As Is" processes to the new "To Be" situation. This is essentially the 'business requirement elicitation and analysis' phase. A requirement database has been shared among the champion partners.

In the third phase, the 'requirement specification' phase, the business requirements are matched with IT requirements devised to enable technical partners to design the specific architecture and the set of interfaces and IT artifacts to be deployed in each champion. A core set of IT artifacts has been identified as a common ground as well (see Deliverable D2.1). This allows consortium partners to identify, by backtracking the logical links of the data structure, what is the added value of each specific IT artifact and to what common needs it may contribute to satisfy.

# 2 Rhone Alpes champion description

## 2.1 Company description

Georges Pernoud is a mold maker, located in the plastic valley (France). The Company was founded in1971 and is specialized in complex and high kinematic serial tools.

Its business, the world of plastic injection is constantly growing every year.

Still ten years ago, the European Industry was in vanguard of this business due to its technological advance. Since then Low Cost Countries started to take over both, the production of the parts itself and the one of the related Production Systems, especially in the automotive industry sector.

In order to compete against low cost countries today it is vital for European companies to ensure and consolidate their technological advantage. Without innovation, there is no chance to survive.

This is why Pernoud has always invested into new technologies like Robotics for molding or robotics and other new technologies, e.g. Multitube, for plastic parts production.

In this spirit Pernoud continues to look forward to develop the future proof, smart, connected and fully automated mold for plastic injection, as an experimentation part of the BEinCPPS H2020 project. .

## 2.2 Use case description/intervention performed

**The Rhone-Alpes BEinCPPS Innovation Hub** is led by **CEA LIST and Georges Pernoud**. CEA provides training and business innovation services for smart systems and CPS technology for manufacturing process digitalization and virtualization. Georges **Pernoud** is designer and provider of a demonstrator for pilot experiments. Latter address a smart tool for plastic part production.

In this framework and with the help of the CEA, Pernoud is targeting to develop Tomorrow's Mold: a fully automatized, smart and connected mold

The experiments core is a Cyber Physical Production System monitoring and controlling a plastic injection mold process. The CPPS is composed of a mold that is the result of a manufacturing process that will involve digital design software and CAM machining tools, and a control device which, as a black box, will record environmental sensor data for characterization and monitoring of the process. Further details on the business processes under consideration and a high-level technical description of the system architecture can be found in the BEinCPPS Deliverable D8.1a "Rhône-Alpes Regional Ecosystem Scenarios and Requirements".

# 3 Experiment plan

## 3.1 List of Experiments (GP)

*Table 1 Experiment plan*

| Exp. Number | Experiment Name | Experiment Description | | | | |
|---|---|---|---|---|---|---|
| | | **Objective** | **Time** | **Location** | **Involved stakeholders** | **Involved resources** |
| *1* | *First desk experiment* | *Acquire data from thermocouple and send data to a cloud system* | *June 2016-July 2016* | *Saclay* | *Juan Cadavid (CEA) and Nicolas Rapin (CEA)* | *Beagle Bone Black, IDAS, Wirecloud,* |
| *2* | *First core experiment* | *Acquire data from a mold, send those data to a cloud system and follow up production* | *August 2016* | *Oyonnax* | *Juan Cadavid (CEA), Valentin Charreton (GP). And 2 others people involved (Essmotech and Pernoud)* | *Beagle Bone Black, IDAS, Wirecloud, Injection machine,* |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | *from the CPPS user interface* | | | | *mold.* |
| *3* | *Second desk experiment* | *Acquire data from two thermocouples simulate alerts and persist data on the CPPS device* | *December2016 - January 2017* | *Saclay* | *Juan Cadavid (CEA), Nicolas Rapin (CEA) and Mauricio Alfarez (CEA)* | *Beagle Bone Black, IDAS, Wirecloud, mold piece.* |
| *4* | *Second core experiment* | *Acquire data on a mold during production, persist data and alerts on production workstation* | *February 2017* | *Oyonnax* | *Juan Cadavid (CEA), Valentin Charreton (GP). And 2 others people involved (Essmotech and Pernoud)* | *Beagle Bone Black, IDAS, Wirecloud, Injection machine, mold.* |

*Table 2 Business Process and Business Requirements*

| **Exp. Number** | **Experiment Name** | **Business Process** | **Business Requirements (BR)** |
|---|---|---|---|
| 1<br><br>2 | First desk experiment<br><br>First core experiment | Equipment Setup | BR36 - The operator must be able to parameterize the monitoring protocol i.e. the physical properties to monitor, their accepted values and the alerts to be raised in case of malfunction.<br>BR37 - The IT responsible should be able to deploy different configurations for a specific mold from a library of sensor configurations (pressure, temperature) and actuators (linear, circular) |
| | | Equipment Monitoring | BR39 - The operator should be able to monitor the current usage of the mold within the injection process i.e. current phase of the injection cycle<br>BR41 - The operator should be alerted of anomalies in the injection process, namely temperature and pressure spikes<br>BR42 - The operator and production manager should be able to access a digital-twin model-based view of the deployed molds and their current state |

| | | | |
|---|---|---|---|
| 3<br><br>4 | Second desk experiment<br><br>Second core experiment | Equipment Setup | BR36 - The operator must be able to parameterize the monitoring protocol i.e. define which physical properties to monitor, the frequency, and the alerts that should be raised in case of malfunction<br>BR37 - The IT responsible should be able to deploy different configurations for a specific mold, from a library of sensor configurations (pressure, temperature) and actuators (linear, circular) |
| | | Equipment Monitoring | BR39 - The operator should be able to monitor the current usage of the mold within the injection process i.e. current phase of the injection cycle<br>BR40 - The production manager should be able to monitor all molds in use in a production site at once<br>BR41 - The operator should be alerted of anomalies in the injection process, namely temperature and pressure spikes<br>BR42 - The operator and production manager should be able to access a digital-twin model-based view of the deployed molds and their current state<br><br>BR47 - The system should be available for every injection cycle; if cloud is not available, the data should be stored locally.<br>BR48 - The system should be able to handle large volumes of data. In case the storage is saturated, it should warn the system administrator to take measures.<br>BR49 - The system should be able to tolerate failures regarding mal-functioning equipment, namely unfunctional sensors and actuators. It should continue data acquisition with the available sensors |
| | | Equipment Maintenance | BR43 - The moldmaker should have access to real-time data on the long-term utilization of the mold i.e. the last million injection cycles, in order to request maintenance operations |

*Table 3 Business Objectives and KPIs*

| **Exp. Number** | **Experiment Name** | | | | | |
|---|---|---|---|---|---|---|
| | | **Business Process** | **Business Objective** | **BPI** | **BPI “AS IS” value** | **BPI Target ”TO BE” value** |
| 1 | First desk experiment | Equipment Setup | To decrease the costs of injection process ramp-up | Time to set up the smart mold for monitoring by an operator | 1 hour | 5 Minutes |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | Equipment Monitoring | To decrease operator's reaction time in case of anomalies in the injection process | Operator’s reaction time | 5 minutes | 1 minute |
| 2 | First core experiment | Equipment Setup | To decrease the costs of injection process ramp-up | Time to set up the smart mold for monitoring by an operator | 1 hour | 5 Minutes |
| | | Equipment Monitoring | To decrease operator's reaction time in case of anomalies in the injection process | Operator’s reaction time | 5 minutes | 1 minute |
| 3 | Second desk experiment | Equipment Setup | To decrease the costs of injection process ramp-up | Time to set up the smart mold for monitoring by an operator | 20 minutes | 5 minutes |
| | | Equipment Monitoring | To decrease operator's reaction time in case of anomalies in the injection process | Operator’s reaction time | 5 minutes | 1 minute |
| | | Equipment Maintenance | To optimize maintenance operations | Reduce the time for expert examination of the mold | 1 work day | Half work day |
| 4 | Second core experiment | Equipment Setup | To decrease the costs of injection process ramp-up | Time to set up the smart mold for monitoring by an operator | 10 minutes | 5 minutes |
| | | Equipment Monitoring | To decrease operator's reaction time in case of anomalies in the injection process | Operator’s reaction time | 5 minutes | 1 minute |
| | | Equipment Maintenance | To optimize maintenance operations | Reduce the time for expert examination of the mold | 1 work day | Half work day |

# 4 Experiment Results and Business Assessment

## 4.1 Business requirements (GP)

*Table 4 Business Requirements Assessment*

| Exp. Number | Experiment Name | Business Requirements (BR) | BR Fulfilled (Yes/No) | Comments |
|---|---|---|---|---|
| 1 | First desk experiment | BR36 | Yes | |
| | | BR37 | Yes | Only sensors part |
| | | BR39 | Yes | |
| | | BR41 | Yes | |
| | | BR42 | Yes | |
| 2 | First core experiment | BR36 | Yes | |
| | | BR37 | Yes | Only sensors part |
| | | BR39 | Yes | |
| | | BR41 | Yes | |
| | | BR42 | Yes | Basic visualization through cloud widgets (FIWARE WIRECLOUD) |
| 3 | Second desk experiment | BR36 | Yes | |
| | | BR37 | Yes | Only sensors part |
| | | BR39 | Yes | The experiment consisted of only one deployed mold |
| | | BR40 | Yes | |
| | | BR41 | Yes | |
| | | BR42 | Yes | Basic visualization through cloud widgets (FIWARE WIRECLOUD) |
| | | BR47 | Yes | |
| | | BR48 | Yes | |
| | | BR49 | Yes | |
| | | BR43 | Yes | |

| | | | | |
|---|---|---|---|---|
| 4 | Second core experiment | BR36 | Yes | |
| | | BR37 | Yes | Only sensors part |
| | | BR39 | Yes | The experiment consisted of only one deployed mold |
| | | BR40 | Yes | |
| | | BR41 | Yes | |
| | | BR42 | Yes | Basic visualization through cloud widgets (FIWARE WIRECLOUD) |
| | | BR47 | Yes | |
| | | BR48 | Yes | |
| | | BR49 | Yes | |
| | | BR43 | Yes | |

## 4.2 Business KPIs (GP)

*Table 5 Business Objectives Assessment*

| | | | **Business Assessment** | | | | |
|---|---|---|---|---|---|---|---|
| **Exp. Number** | **Experiment Name** | **Business Objectives** | **BPI.** | **BPIs "As is" value** | **BPIs Target "To be" value** | **BPIs Actual value** | **Comments** |
| 1 | First desk experiment | To decrease the costs of injection process ramp-up | Time to set up the smart mold for monitoring by an operator | NA | 5 Minutes | 1 hour | As the smart mold did not exist previously, there is no AS IS value. |
| | | To decrease operator's reaction time in case of anomalies in the injection | Operator's reaction time | Average 15 minutes | 1 minute | 5 minutes | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | process | | | | | |
| 2 | First core experiment | To decrease the costs of injection process ramp-up | Time to set up the smart mold for monitorin g by an operator | NA | 5 Minutes | 1 hour | As the smart mold did not exist previously, there is no AS IS value. |
| | | To decrease operator's reaction time in case of anomalies in the injection process | Operator' s reaction time | | 1 minute | 5 minutes | |
| 3 | Second desk experiment | To decrease the costs of injection process ramp-up | Time to set up the smart mold for monitorin g by an operator | NA | 5 minutes | 20 minutes | As the smart mold did not exist previously, there is no AS IS value. |
| | | To decrease operator's reaction time in case of anomalies in the injection process | Operator' s reaction time | Average 15 minutes | 1 minute | 5 minutes | |
| | | To optimize maintenan ce operations | Reduce the time for expert examinati on of the mold | 1 work day | Half work day | Estimated half work day | The duration and scope of the experiment do not allow an exact measure |
| 4 | Second core experiment | To decrease the costs of injection process | Time to set up the smart mold for monitorin | NA | 5 minutes | 10 minutes | As the smart mold did not exist previously, there is no |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | ramp-up | g by an operator | | | | AS IS value. |
| | | To decrease operator's reaction time in case of anomalies in the injection process | Operator's reaction time | Average 15 minutes | 1 minute | 5 minutes | |
| | | To optimize maintenance operations | Reduce the time for expert examination of the mold | 1 work day | Half work day | Estimated half work day | The duration and scope of the experiment do not allow an exact measure |

## 4.3 Questionnaire results

*(See Annex 1)*

# 5 Overall lessons learned & recommendations

To run an experiment, a person skilled in numeric or programming technologies is needed, in our case Pernoud needed a member of the CEA team to run the experiment. This is why scheduling the experiments became challenging as everyone needed to be available from CEA and Pernoud. Also the equipment availability was limited, injection machine or even the physical mold itself used to run the experments (see validity of the solution). As a remedy the Pernoud team has been trained by CEA and practiced so they can now run experiments on their own.

The chosen solution is good and adequate for what Pernoud wants to achieve, however, due to the availability of people and equipement of the Experiments needed to be delayed or could not be executed at all. During February, the NGSI proxy was not available and without it, we could neither monitor nor store data in the cloud. So experiments had to be delayed until this proxy was available again. To avoid this issue to happen again, all the system infrastructure required by the Smart Tool will be hosted on Pernoud servers.

The networking aspect of the experimentation has not been addressed, and the completed experiments have shown that an instable connection between the device level of the CPPS and the cloud level could hamper the effectiveness of the system. The lack of an optical fiber increases the latency between embedded system and cloud system. When the number of exchanged data will increase, the optical fiber will become compulsory in order to successfully use the Setup.

# 6 Conclusion

The first iteration of the iteration provided satisfying results, has set the background and produced lessons learned to pursue the development in the second iteration. The following business requirements, which were not addressed in the first iteration, are the focus of this second iteration:

- BR35: The operator must be able to set up the mold on top of the injection machine, without needing hydraulic pumps to power inner-mold mechanical movements
- BR38: The operator must be able to switch the version of the produced part, without needing to open the mold cage of the injection machine
- BR44: The operator should be warned when a mold under production is requiring a maintenance operation
- BR45: The production manager should receive a report within a pre-configured frequency (by default: a week) notifying the molds which will require soon a maintenance operation
- BR46: The moldmaker should have access to real-time data on the long-term utilization of the mold i.e. the last million injection cycles, in order to provide an adapted response to the customer's guarantee support requests

# 7 ANNEX 1

## Lessons Learned Questionnaire

- What worked well during the experimentations? Why?

Data acquisition and online monitoring on digital support (computer, smartphone…) worked well (when tools were available).

- What did not work well during the experimentations? Why?

Availability of some tools which were not online or unreachable during experiments.

- What unexpected issues occurred and how did you fix them? Did you develop any useful solutions?

The experiments have shown some unexpected errors. While this has reduced the time we had for real tries, it allowed us to see that non-isolated thermocouple weren't suitable which is why we switched to isolated ones.

Secondly we have to work on the last type of error which we have ignore to continue the experimentation. This error consisted in recurrent false readings from the sensors, when these are embedded inside the mold; therefore it was only present during production experiments, and not the desks experiments where the CPPS was used in an isolated manner. The causes of this error are still unknown to us; in the next iteration we have to fix it or at the minimum to understand the cause.

- Did any opportunity emerge during the experimentation? Which kind?

Not yet

- Were the project goals attained? If not, what changes would help to meet goals in the future?

The goals were attained for the first iteration, concerning 10 business requirements. The remaining business requirements (B35, B38, B44, B45, and B46) must be addressed to attain the remaining goals.

- What are the three most important lessons learned on the experiments?

Be trained, have control on each tools of the experiment.

- What recommendations would you make to others doing similar projects?

| **Strengths** | **Weaknesses** |
|---|---|

| | |
|---|---|
| *The first iteration of the experimentation worked well in the sense that the most essential requirements for Georges Pernoud have been met, satisfying the company and motivating for the second iteration to cover the remaining business requirements.* | *Some of the business requirements cannot be assessed during the experiments scheduled for the Rhône-Alpes ecosystem e.g. the optimization of maintenance operations cannot be exactly measured, since this will only be known with precision after at least five years of deployed molds.* |
| *The digitalization of the mold for plastic injection has become a de-facto example for Industry 4.0 in the plastics sector, as well as example for the servitisation of any industrial equipment. The technical skills and lessons learned can be applied for other experimentations, in this industrial sector and others.* | *The planning and development of the experimentation focused strongly on software, ignoring for a large part the hardware aspect, with the team not having enough skills to choose, acquire and set up the hardware. Within the resources allocated for the project, the team sought access to experts for help in this domain.* |
| **Opportunities** | **Threats** |

**Lessons Learnt**

*-Multidisciplinary collaboration and access to experts in different domains (ICTs, manufacturing, mechanical, electronics) is essential*

*-The software and ICTs aspect of CPPS is only a small part of the development of these experimentations.*

*-Focus on short-term business process indicators, which might be measured within the experimentation plan*