Innovation Action Project

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D4.5 – Lombardy Regional Ecosystem Business Assessment and Recommendations

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Deliverable Peer review summary

Id.	Addressed	Comments

1	yes	Align deliverable D4.5 and D3.7

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Executive summary

D4.5 report will contribute to the deliverables of WP4 of the second half of the project, since experiments' results and lessons learnt will be fed into the second iteration of the development cycle.

D.4.5 refers to the experiment implemented in the Lombardy Champion: a Portable Testing Unit to perform Statistical Quality Check on Microwave Ovens and Refrigerators. In particular, This document addresses the transformation towards CPS of the current ZHQ system in Whirlpool, that will allow the usage of mobile testing stations, enhanced operator interaction and auto-reconfiguration of the testing stations, thus improving throughput and effectiveness of the system.

The methodology followed to gather BEinCPPS champions' business requirements, is the well-known spiral development approach. The main phases of BEinCPPS requirement engineering cycle are:

- Scenario Analysis
- Business requirements elicitation and analysis
- Requirements Specification
- Requirements Verification and Validation

Deliverable D4.1 built up the "Scenario Analysis", to understand how the ZHQ works in the AS-IS situation, deeply explaining the main problems with the current ZHQ implementation and described how those shortcomings were going to be addressed by the new system developed in the scope of BEinCPPS. Overall, the CPS implementation will improve the quality assurance system by using mobile phone apps, improving data interoperability, elaborating testing data in terms of time series to understand the product behavior. The experiment results will demonstrate how the Portable Testing Unit enables a Quality department to easily adopt a more economic, flexible and programmable system to replace a more traditional and rigid approach, achieving a more accurate testing procedure at the same time.

In the first phase of the project, 1 experiment with two participants addressing 12 business requirements of the total 16 identified has been conducted in Whirlpool and some more are planned in the next months. During the next planned experiments the testing rule and the overall test process will be iteratively checked out and improved directly in the WHR factory.

For each of the experiments, three main BPs have been identified during the "Scenario Analysis":

1. Create test rule
2. Execute test
3. Store and analyze test data

Then, in "Business requirements elicitation and analysis" phase, a set of 16 Business Requirements (BRs) have been identified for each of the BPs.

The champions have evidenced the outcomes of the experiments in terms of the specific Business Objectives (BOs) and Impacts identified during the scenario analysis:

1. To minimize time for new rule generation
2. To maximize personnel productivity
3. To improve information available

Moreover, for each of the BPs, the achieved benefits have been described using facts and figures and specific Business Process Indicators (BPIs) have been identified and monitored:

1. Time for new rule generation
2. ZHQ Productivity
3. SIR and FOR

The first business assessment highlighted that the compliance with the identified BR was achieved and the BOs were accomplished, measured according to the specific indicators.

Finally, a questionnaire was conducted to evaluate the lessons learnt during the experimentation. In particular, the interview was mainly addressing the following topics:

- Major obstacles
- Key learning
- Best Practices
- Next steps

The main lessons learnt from the first assessment of the Lombardy Champion Experimentation and recommendation for the implementation of CPS are the following:

- During the experimentation, the Industrial **Quality Process Analysis** has to be done in a very detailed mode.
- It is important to have a **harmonized definition of the standard** to be applied in the ZHQ production.
- **Information and data storing** is a necessary activity to have a very fast and useful test reporting view.
- A **deep knowledge** of the field of application, appliances in this case, and **experience** in testing process integration is fundamental.
- The specific **polices of the company** have to be clearly kept in mind since the design of the Integration of different Information Systems needs to be developed accordingly.
- The integration of Analytics into the system is needed in order to analyze and testing data.

1 Introduction

1.1 Introduction

This document provides the assessment of the final results achieved in the Champion experimentation, including a description of the defined Business Performance Indicators (BPIs) measured. The results achieved during the process, the lessons learned and recommendations for the implementation of CPPS are also documented.

In particular, after an insight on the description of the methodology followed for the requirements gathering in section 1, the Lombardy Champion, Whirlpool, is described in section 2. The experimentation plan id deeply depicted in section 3, while section 4 is dedicated to the results of the experiments and the lessons learnt.

1.2 Contributions to other WPs

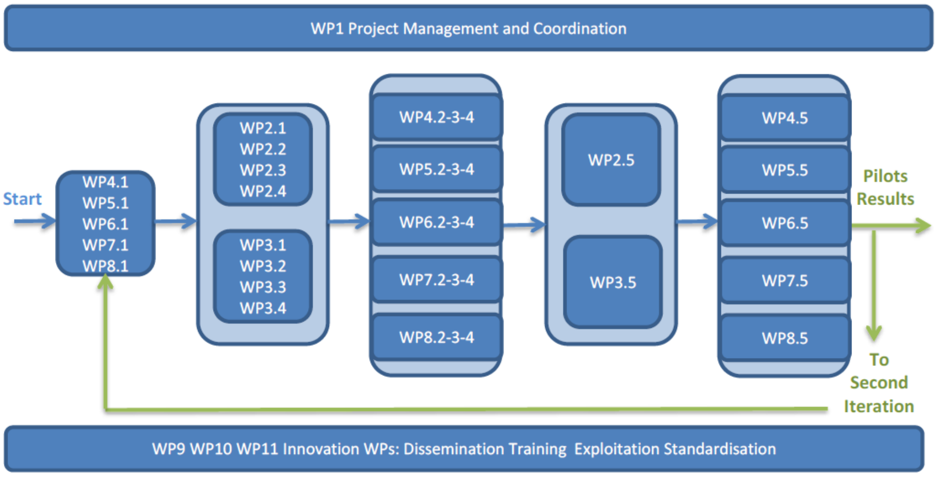

Figure 1: BEinCPPS PERT diagram

Deliverable 4.5 outputs, as well as similar contribution coming from the other regional champions' experiments, will significantly contribute to the second part of the project. In particular, experiments' results and lessons learnt will be fed into the second iteration of the development cycle. The second half of the project will begin with a second scenario analysis, built on the previous outcomes (the requirement database and requirement documents which contain the verification and validation results).

1.3 Contributions to other deliverables

D4.5 will contribute to the deliverables of WP4 of the second half of the project.

1.4 Methodology

In D4.1 *"Lombardy Regional Ecosystem Scenarios and Requirements"* an initial description of business objectives, functional requirements and technical challenges has been performed.

The methodology followed to gather BEinCPPS champions' business requirements, is the well-known spiral development approach, here described in Figure 2. 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.

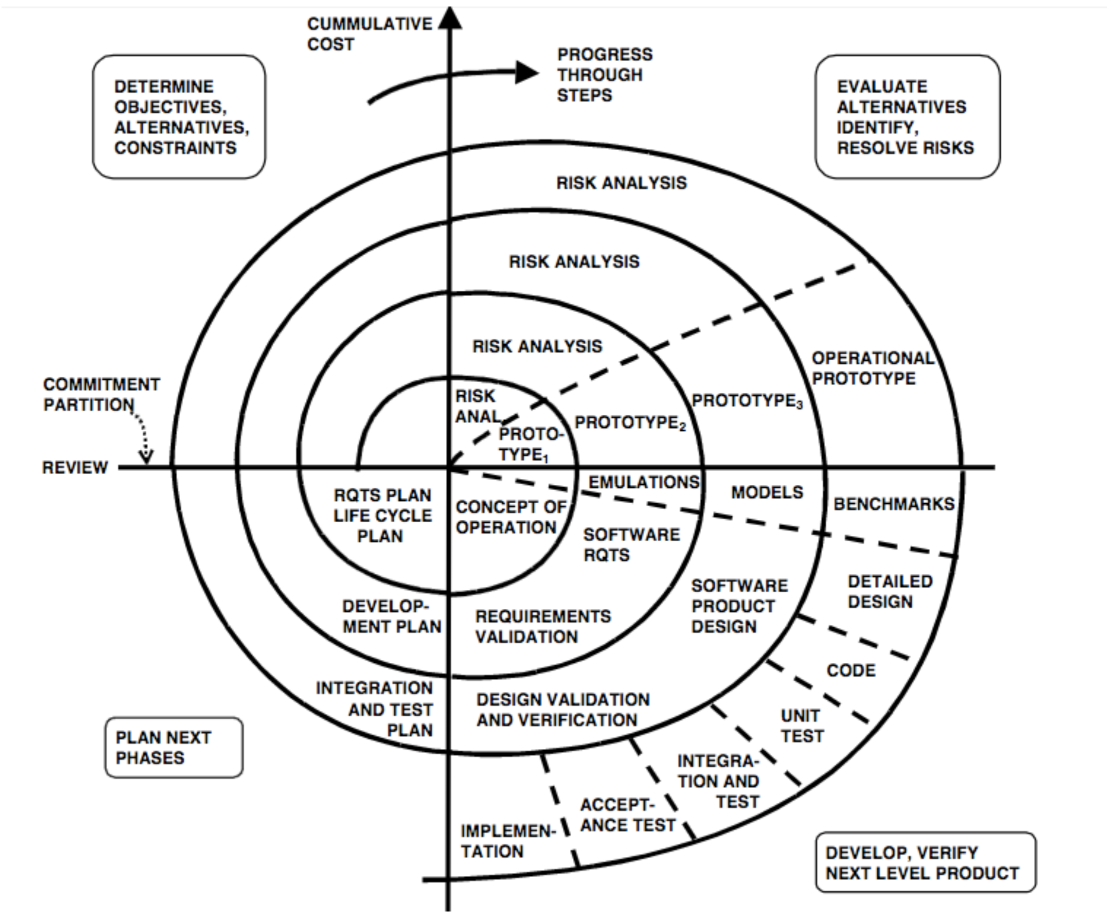

Figure 2: Boehm, B. (2000) Spiral Development: Experience, Principles, and Refinements, SPECIAL REPORT CMU/SEI-2000-SR-008

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 3.

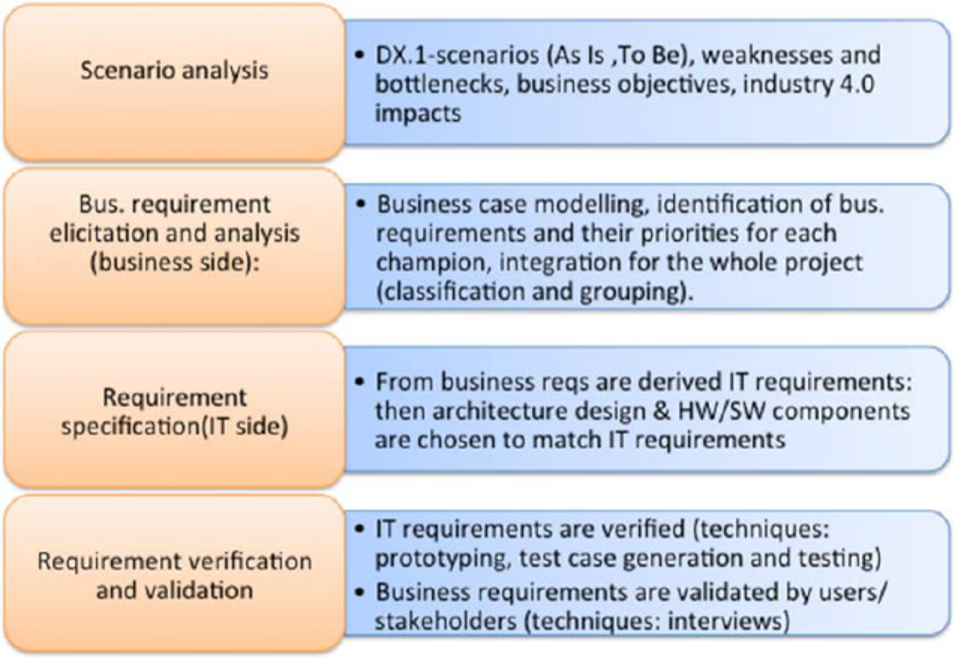

Figure 3: BEinCPPS business engineering (adapted from Sommerville, 2007)

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. This phase has been performed in the first three months of the projects and it is described in D4.1 *"Lombardy Regional Ecosystem Scenarios and Requirements"*, that contains the description of the use-case from both business and requirements aspect in its AS-IS situation. It also provides a proposal of the TO-BE situation from a functional point of view, trying to identify technical areas of interest and identifying the potential benefit, tangible and intangible of its realization.

The second phase concerns the "Business requirements elicitation and analysis". During this phase, happened in the first three months of the project, 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 have been collected and refined through internal meetings held in Whirlpool and involving Global information Systems, Advanced Manufacturing, Manufacturing Quality, Manufacturing R&D. WP4 partners has been involved in technical meetings and phone conferences to share initial requirements, to gather feedback and to help further refinements. Then, business requirements have been 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. This activity is reported in detail in D4.3 *"Lombardy Champion BEinCPPS Integrated System"*.

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 4 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 V&V results).

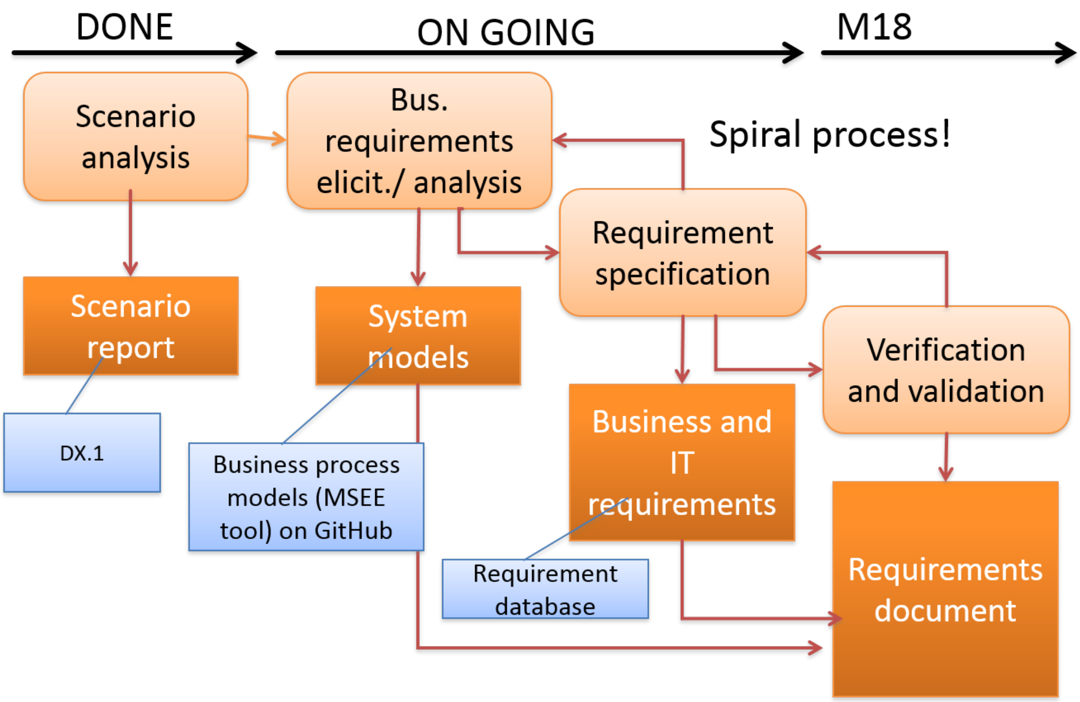

Figure 4 Spiral approach of BEinCPPS requirements. engineering method

The data structure supporting the project is shown in Figure 5, highlighting especially the scenario analysis, requirements elicitation and requirement specification. In particular, as already explained, each champion has identified one business scenario or area of intervention, with its specific business objectives and indicators, 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 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.

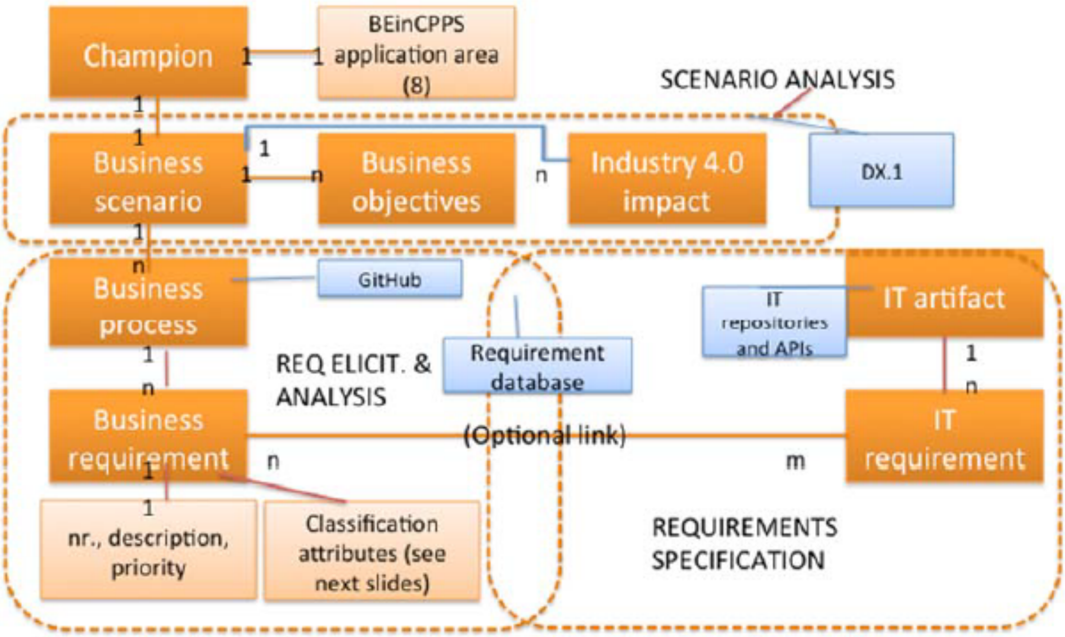

Figure 5 BEinCPPS requirement eng. data structure

2 Lombardy Champion description

This section provides an overview of the Lombardy Champion, Whirlpool, briefly recapping the use-case interested within the project, namely a Portable Testing Unit to perform Statistical Quality Check on Microwave Ovens and Refrigerators.

2.1 Company description

The production site which has been interested by this research belongs to Whirlpool EMEA and it is located in Biandronno (VA). The plant is focused on the production of medium-high-end white goods.

The Statistical Quality Control stage is shared among all the products of the plant, and is managed horizontally in relation to the four production lines. Statistical Quality Controls still play a crucial role in white good manufacturers toward the Zero Defect goal, and implies a sophisticated organization in which humans, machines and computers have to cooperate in perfect way. Statistical Quality Control in Whirlpool is done by the Zero Hours Quality department (ZHQ), and simulates the first usage of Whirlpool products at the customer's premises. Statistical Quality Control does not replace quality tests that are performed during the whole production, but it is done in addition to it. Tests on the line have to be performed in a time compatible with the production cycle time, and for the most complex product it takes up to 10 minutes. This time is not enough to verify in detail all the behaviors of the appliance, so a statistical sample of the production (3% to 5% products sampled from each produced batch) is tested in a specialized laboratory of the factory, the ZHQ. This is done to emulate the behavior of the white goods as it is in the customers' premises, in order to test the actual functioning of the products. Currently, ZHQ is implemented as a CPS where products under test are connected to a number of fixed workstations. Tests are driven by rules that are stored in a Factory database, and results are collected in the same storage facility.

The Zero Hours Quality (ZHQ) department of the production system of Biandronno is intended to provide further statistical control of the conditions and performances of the appliances produced.

Deliverable D4.1 built up the "Scenario Analysis", to understand how the ZHQ works in the AS-IS situation, deeply explaining the main problems with the current ZHQ implementation and described how those shortcomings were going to be addressed by the new system developed in the scope of BEinCPPS.

In particular, the weaknesses of the AS-IS system are reported below:

1. Mobility. Operators are required to frequently interact with the appliance under test and a full help from system is available only at few specific stations

2. Scalability. A full implementation of ZHQ requires important investments in hardware and software and is not easily scalable down and up

3. Data Interoperability. Despite a standard system, ZHQ still lack a full integration with other company systems (ERP)

4. Threshold Based Failure Logic. Availability of time series data from many of the physical quantities is not yet fully exploited: many product exhibiting anomalous behavior can be recognized by human but not yet by machines

5. Flexibility. Despite its high degree of programmability provided by System Architecture, some behaviors of the system are still depending of specified product families. The new testing approach needs to have the technical modification of the appliance testing behavior.

2.2 Use case description/intervention performed

The experiment implemented in the Lombardy Champion refers to a Portable Testing Unit to perform Statistical Quality Check on Microwave Ovens and Refrigerators. This experiment is dedicated to the White Good industry and is focused on the CPS-ization of Statistical Quality Check.

The current practice relies on dedicated building and fixed, bulky equipment, which limit the typologies and the depth of tests. In the new state quality managers and operators will rely on a portable, flexible and smart Testing Unit, which enables the easy adaptation of the statistical quality check to the great variety of customer requirements. A specific production batch of any produced models will be tested using a digital testing protocol. The quality operator will move the portable lab where the product is located and will be guided through test steps using a mobile device. Moreover, several Testing Units running in parallel will share data and communicate to each other variations in testing programs or parameters without the intervention of the operator.

The transformation towards CPS of the current ZHQ system in Whirlpool will allow usage of mobile testing stations, enhanced operator interaction and auto-reconfiguration of the testing stations, thus improving throughput and effectiveness of the system. The introduction of portable testing stations are implemented thanks to devices embeddable into the physical testing stations, which can both communicate, compute data and control stations. In particular PLCs will be used in a sensors/actuators portable unit, which will communicate with the portable controller unit. Together, the sensors/actuators unit and the controller unit can be used as a modular portable testing station, which completely replaces the currently used fixed testing stations. The modular approach allows the system to be adapted to completely different products (e.g. more complex) without changing the control layer.

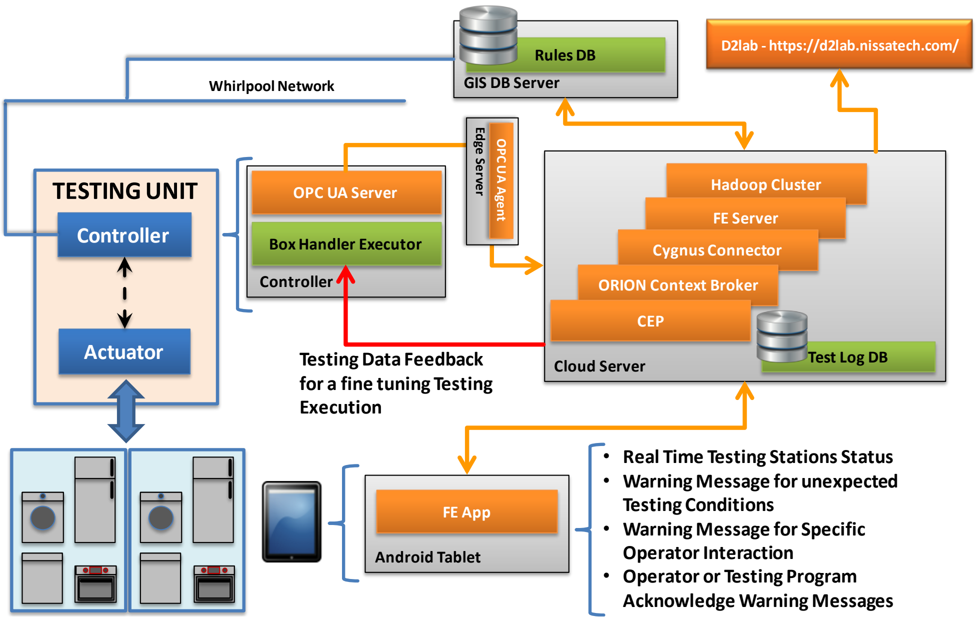

Figure 6 WHR architectural scheme

Furthermore, in the current situation quality testing is based on threshold rules, focused on the identification of the most critical situations (e.g pump does not provide target pressure). With the CPS implementation it will be possible to highlight, with higher detail and in real time, a wider set of potential problems, for instance by comparing the dynamic behavior of each component to the expected one.

Overall, the CPS implementation will improve the quality assurance system by using mobile phone apps, improving data interoperability, elaborating testing data in terms of time series to understand the product behavior.

Accordingly, Whirlpool Experiment objectives mainly aim at:

1) Enhancing the flexibility of product testing procedures and optimizing the productivity of the Statistical Quality Check department
2) Improving the testing system's capability of revealing potential product failures and, as consequence, reducing the probability of sending defective products to the market
3) Reducing the cost and time to install or scale up the testing capacity of a factory

The experiment results will demonstrate how the Portable Testing Unit enables a Quality department to easily adopt a more economic, flexible and programmable system to replace a more traditional and rigid approach, achieving a more accurate testing procedure at the same time.

3 Experiment plan

This section presents the plan of experiments conducted in Whirlpool. Business Processes (BP), the related Business Requirements (BR) as well as Business Objectives (BO) and Indicators for each BPs will be explained.

3.1 List of Experiments (WHR)

During the first phase of the project, 1 experiment with two participants has been conducted in Whirlpool and some more are planned in the next months. Table 1 shows the experiments conducted hitherto and planned in the short term, reporting the stakeholders involved.

Table 1 Experiments description

Exp. Number	**Experiment Name**	**Objective**	**Time**	**Location**	**Involved stakeholders**
1	ZHQ MW ovens: testing rule execution	*First setup and testing rule execution testing*	*21/3/2017-31/3/2017*	*Cassinetta OE Lab*	• *OE Quality Department* • *MW Plant Quality Manager* • *MW Quality operator*
2	ZHQ MW ovens: set up and preparation (part I)	*Setup the Equipment and preparation of the quality Control test process*	*Planned end of April-May 2017*	*Cassinetta OE Lab*	• *OE Quality Department* • *MW Plant Quality Manager*

3	ZHQ refrigeration: equipment and testing process calibration	*Test the equipment and the new testing process in quality Production Area + Data analytics*	*Planned June/July 2017*	*Cassinetta MW Plant*	• *OE Quality Department* • *MW Plant Quality Manager*

The planned experiments 2 and 3 are particularly important: during them the testing rule and the overall test process will be iteratively checked out and improved directly in the WHR factory, with the participation of the Quality manager and the MW plant Quality Manager, with the support of an operator of the CSQ area (Laboratory Experiment).

During the "Scenario Analysis", Whirlpool identified the relevant CPS-ization scenarios and the main Business Processes (BPs). In particular, for each of the experiments, three main BPs have been identified:

- Create test rule
- Execute test
- Store and analyze test data

Then, in the second phase, "Business requirements elicitation and analysis", a set of 16 Business Requirements (BRs) have been identified for each of the BPs (see Table 2). The BRs have been collected and refined through internal meetings held in Whirlpool and involving Global information Systems, Advanced Manufacturing, Manufacturing Quality, Manufacturing R&D, and then organized in a database for further processing, integration and classification. Table 2 reports the list of BRs, according to the related BPs, with the indication of requirements related to functionalities to be addressed in the second iteration of the project.

Table 2 Business Process and Business Requirements

Business Process	**Business Requirements (BR)**
Create test rule	BR01 - Acquisition of hystorical data on tests – Critical
Execute test	BR02 - Support by mobile for single test run - Critical BR03 - Execution of the test program on the portable testing unit - Critical BR04 - Support by mobile to follow multiple testing units - Critical BR05 - Test program change - Preferred BR06 - Sampling rate information - Preferred BR07 - Sampling rate change – Preferred (2^nd iteration) BR08 – Support for test data analysis on the mobile device – Preferred (2^nd iteration) BR09 - Support for test data confirmation on the mobile – Preferred

	(2^nd iteration) BR10 - Additional data by user via mobile - Optional BR11 - Support for multimedia data acquisition via mobile device - Preferred BR13 - Quantities to be tested by the portable testing uni - Critical BR14 - M2M communication of the testing units – Critical (2^nd iteration)
Store and analyze test data	BR12 - Data analytics for test results – Critical BR15 - Data Persistence – Critical BR16 - Data Security – Critical

Requirements such as BR07, concerning providing information on the shop-floor of possible change of the sampling rate of the products coming from the production lines, or BB08 and BR09, related to providing further functionalities to the operator on the mobile interface during test execution, will be addressed in the next iteration.

The same, is planned on the next iteration requirement BR14, relating to M2M communication among the machines, which, besides further development, requires acquisition of another testing station.

In the context of the project requirements engineering methodology, with reference to the methodology described in section 1.4, the champions have evidenced the outcomes of the experiments in terms of the specific Business Objectives (BOs) and Impacts identified during the scenario analysis. Moreover, for each of the BPs, specific Business Process Indicators (BPIs) have been identified and monitored in order to assess the impact of the interested intervention on the business. This information is reported in Table 3.

Table 3 Business Objectives, Impacts and Indicators

Business Process	**Business Objective**	**Business Impact**	**Industry 4.0 Impact**	**BPI**	**Benefits description**	**Facts and figures**
Create test rule	To minimize time for new rule generation	Optimize ZHQ flow time	Efficiency	Time for new rule generation (minutes)	Now WHR quality managers sets up test instructions and program on the basis of the test information of similar products, by relying on personal knowledge.	WHR estimate that test programming and preparation might be reduced, on average, by 10 minutes in 40 minutes
Execute test	To maximize personnel productivit y	Optimize process costs and quality costs	Efficiency	ZHQ Productivity (number of tests/shift/per son)	Currently WHR ZHQ productivity is 15 test/shift/person. Efficiency might be gained as well in deployment time of the solution in a new WHR plant, that is a process not included in the	WHR estimates to get a 20 test/shift/person productivity.

					intervention area.	
Store and analyze test data	To improve information available	Reduce SIR and FOR	Quality	SIR (calls/units sold) FOR (number of defects/unit produced)	WHR cannot share critical business information such as absolute values of the mentioned indicators. Anyway, SIR reduction might be quantified in figures in the order of million €. The effects on SIR go beyond the project scope, since they will be visible in the long term.	WHR estimates the reduction of SIR might be in the order of 10-15%, of defect rate in the order of 2-3%.

4 Experiment Results and Business Assessment

This section includes a first business assessment, performed in the first half of the project, further to execution of the first experiment listed in Table 1. In particular, the compliance with the identified BR during the experiment is evaluated and the achievement of the BOs is measured according to the specific indicators. Then, the results coming from a questionnaire to evaluate the lessons learnt during the experimentation have been provided.

4.1 Business Requirements (BRs)

Table 4 reports the identified BRs (with the exclusion of those planned for second iteration), explaining whether they have been fulfilled during experimentations.

Table 4 Business Requirements Assessment

Business Requirements (BR)	**BR Fulfilled (Yes/No)**	**Comments**
BR01 - Acquisition of historical data on tests	*Yes*	*If No, explain the main reasons*
BR02 - Support by mobile for single test run	*Yes*	*If No, explain the main reasons*
BR03 - Execution of the test program on the portable testing unit	*Yes*	*If No, explain the main reasons*
BR04 - Support by mobile to follow	*Yes*	*If No, explain the main reasons*

multiple testing units		
BR05 - Test program change	*Yes*	*If No, explain the main reasons*
BR06 - Sampling rate information	*Yes*	*If No, explain the main reasons*
BR10 - Additional data by user via mobile	*Yes*	*If No, explain the main reasons*
BR11 - Support for multimedia data acquisition via mobile device	*Yes*	*If No, explain the main reasons*
BR13 - Quantities to be tested by the portable testing unit	*Yes*	*If No, explain the main reasons*
BR12 - Data analytics for test results	*Yes*	*If No, explain the main reasons*
BR15 - Data Persistence	*Yes*	*If No, explain the main reasons*
BR16 - Data Security	*Yes*	*If No, explain the main reasons*

4.2 Business Performance Indicators (BPIs)

A set of BPIs has been identified for each of the selected BPs. For each indicator, an "As Is" value, measured during the "Scenario Analysis", have been linked to a "Target" valued that Whirlpool want to achieve. The latter is then compared with an actual value, measured after the solution implementation. Table 5 reports the assessment of the Bos, according to the identified BPIs.

Table 5 Business Objectives Assessment

		Business Assessment				
Business Process (BP)	**Business Objectives (BO)**	**Business Process Indicator (BPI)**	**BPIs "As is" value**	**BPIs Target "To be" value**	**BPIs Actual value measured**	**Comments**
F1 - To create test rule	To minimize time for new rule generation	New rule generation time	*40'*	*10'*	*25'*	*Value still on learning curve.*

F2 - To execute test	To maximize personnel productivity	ZHQ Productivity: Number of tests/shift/ person	*15 tests/shift /person*	*20 test/shift/person*	*18*	*Estimation based on first test done in laboratory.*
F3 - To store and analyze test data	To improve information available	Number of data records stored. Number of abnormal behavior found.	*NA*	*NA*	-	*Value will be actualized after 6 month in production*

4.3 Questionnaire results

An interview to collect the key lesson learnt during the Champion experimentations and recommendations for the implementation of CPS has been conducted to Whirlpool ZHQ department managers (see Annex 1). The interview was mainly addressing the following topics:

- Major obstacles
- Key learning
- Best Practices
- Next steps

Results have then been outlined in Figure 7.

Strengths

- The preparation of the new testing sequence according with the quality standards procedure
- Visualization of the Test Results
- Portability of the system
- Operator interface
- These phases met all the predefined requirements and procedures
- Testing procedures are formalized and not depending on operator skills

Weaknesses

- The acquisition of the right documentation in order to configure the system has been an arduous process, because of the definition of the standard to be applied in ZHQ production
- Need of digital competences of the operators

Lessons Learnt

- Experimentation is a crucial phase to assess the right configuration of the system. It is extremely important to involve quality managers and to collect and store the information.
- Industrial Quality Process Analysis has to be done in detail.
- A deep knowledge of appliances and experience in testing process integration is fundamental.
- The polices of the company have to be highly considered for the Design of the Integration of different Information Systems.

Opportunities

- During the configuration of the system, several areas of improvements were identified

Threats

- Product personalization needs several testing procedures
- Skilled operators

Figure 7 Summary of lessons learnt from Lombardy Champion experimentation

The whole interview transcript can be found in Annex 1.

5 Overall lessons learned & recommendations

The present section reports the main lessons we learnt from the first assessment of the Lombardy Champion Experimentation and recommendation for the implementation of CPS:

- During the experimentation, the Industrial **Quality Process Analysis** has to be done in a very detailed mode. Moreover, during the process a perfect alignment with the Quality Department and a detailed definition of quality procedures is necessary, since experimentation is a crucial phase to assess the correctness of the system configuration.
- It is important to have a **harmonized definition of the standard** to be applied in the ZHQ production since the acquisition of the right documentation to configure the system is an arduous process.
- **Information and data storing** is a necessary activity to have a very fast and useful test reporting view.
- A **deep knowledge** of the field of application, appliances in this case, and **experience** in testing process integration is fundamental. Hence, before starting the experimentation process, the company needs to be sure to have the right necessary knowledge capabilities and build up the right team that will follow the entire process.
- The specific **polices of the company** have to be clearly kept in mind since the design of the Integration of different Information Systems needs to be developed accordingly.
- The integration of Analytics into the system is needed in order to analyze and testing data.

6 Conclusion

In the first phase of the project, 1 experiment with two participants has been conducted in Whirlpool "ZHQ MW ovens: testing rule execution" and some more are planned in the next months. During the next planned experiments, namely "ZHQ MW ovens: set up and preparation (part I)", "ZHQ MW ovens: equipment and testing process calibration" and "ZHQ MW ovens: set up and preparation (part II)", the testing rule and the overall test process will be iteratively checked out and improved directly in the WHR factory.

After the first half of the project, the business assessment of the results highlighted that the experiment conducted so far worked well, accomplishing all the identified Business Requirements and Business Objectives, accurately measured with specific indicators. Furthermore, 12 Business Requirements of the total number of 16 identified ones have been experimented in this first iteration, so that the remaining four are planned for the next iteration experiments.

The lessons learned and the recommendations elaborated through a specific questionnaire will be a fundamental strategic input for the second iteration and the next phase of experimentations.

7 ANNEX 1

Lessons Learnt Questionnaire

1. *What worked well during the experimentations? Why?*

    a. The basic preparation of the new testing sequence in accordance with the quality standards procedure defined by the Quality Manager using the Rule Editor application

    b. Visualization of the Test Results (Display Result application) in order to optimize and calibrate the testing sequence in accordance with the visual inspections and the measures gathered

    c. Portability of the system, in few minutes it is ready to work

    d. Operator interface: simple, but enough for the specific ZHQ application

2. What did not work well during the experimentations? Why?

    a. The experimentation has been characterized by two main aspects: the configuration of the system and the acquisition of the right documentation in order to configure the system. The second point has not been a simple process, because the definition of the standard to be applied in the production ZHQ is not still harmonized. Due to this, we spent a lot of effort and we did an activity in order to get the right tradeoff between different procedures approach.

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

    a. No particular issues emerged, because the system has been designed already oriented for a specific testing application.

4. Did any opportunity emerge during the experimentation? Which kind?

    a. During the configuration of the system, the following areas of improvements have been identified:

        i. Temperature analysis and references curves definition

        ii. Multiple layers for HMI pictures design

        iii. New Layout Box Handler Executor (namely, Controller)

iv. New graphic layout for the measures

v. Commands for external communication during the test rule execution

vi. Summary of the main measures performed during the test execution (stored in DB and visualised in the Display Results)

vii. Integration the Push Buttons Start/Stop/OK/KO/P1/P2/P3/P4... in the HMI

viii. Notes from operator during the test execution

ix. Managing Input/Output TCO/IP messages as variable

x. Local Data (Testing Rules and Results) if there is no connection to the Server DB

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

    a. The goals of the projects have been mostly attained. The design of a testing system oriented to test appliance having different characteristics (MW and Refrigerator) requires experience in knowledge of appliances and in testing process integration.

6. What are the three most important lessons learned on the experiments?

    a. The experimentation is a crucial moment where you can figure out if the system you are using has been correctly configured. According to this, three main actions have to be carefully taken into consideration:

        i. Involvement of the Quality Managers and ZHQ Operators

        ii. Configurability of the system according to the need of the quality procedures

        iii. Storing the information in order to have a very fast and useful test reporting view

7. What recommendations would you make to others doing similar projects?

    a. Industrial Quality Process Analysis has to be done in very detailed mode

b. Knowledge of the characterizes of the elements that are you targets (in this case the appliances)

c. Design of the Integration of different Information Systems in accordance with the polices of the company